Fundamentals of Organic Farming and Gardening

An Instructor's Guide - Revised for 2009

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GOOD FOOD FOR ALL

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As a society, we devalued farming as an occupation and encouraged the best students to leave the farm for "better" jobs in the city. We emptied America's rural counties in order to supply workers to urban factories. To put it bluntly, we now need to reverse course. We need more highly skilled small farmers in more places all across America — not as a matter of nostalgia for the agrarian past but as a matter of national security.

--Excerpt from *Farmer in Chief*, written by Michael Pollan, published in the New York Times Magazine on October 12, 2008.

New opportunities are emerging in Georgia for producers to grow for their own communities as demand for local, organic food rapidly expands. Georgia, as the 6th largest vegetable producing state in the nation, is well-poised to capitalize on these shifting markets. Georgia has an opportunity to be a bigger player in the organic and sustainably-produced market and reconfigure food chains to feed its own residents with fresh, seasonal Georgia grown products. To do this, Georgia must seed farmers into these areas of growth by providing high quality education and resources. Growers must be sought from conventional agriculture, the existing pool of organic growers as well as the next generation of farmers who can be future leaders, educators and advocates for sustainable agriculture.

There is a delicious revolution taking place that is being fueled by:

- increasing consumer demand for "clean," fresh food;
- concern over the population's collective environmental footprint;
- the link between epidemic public health concerns and overall quality of our food;
- and concerns about food safety and food security.

Sustainable and organic agriculture is at the heart of all these issues and can serve as a viable and productive solution for a more sustainable future. As consumer demand for better food outpaces supply, increasing numbers of small-scale sustainable farmers – young and old – are coming onto the scene to meet the need. The benefits of a shift toward sustainable agriculture include:

- protecting the environment by moving away from an industrialized, central food system heavily reliant on fossil fuels;
- providing healthier food to the community and combating obesity and diabetes;
- bolstering local economies by keeping revenue and jobs local;
- building community around a most fundamental need – food.

Why Sustainable & Organic Agriculture?

Beginning in the 1950s, the agricultural system in the U.S. experienced a drastic shift from small-scale family farms to industrial agri-businesses and massive farm complexes that produce the majority of our food; a shift catalyzed by the abundance of cheap fuel. Soaring fuel prices and supply uncertainty, along with the inherent requirements of petroleum-based inputs and cross-country shipping means the costs of conventional farming are increasing every day. With the resulting rise in food prices and growing concern about environmental impact, consumers more and more are seeking responsible

alternatives. Organic agriculture and reliance on sun-power, as opposed to petroleum-power, offers a welcome alternative.

"We're doing something important; something that has meaning to people and to us – and we get fresh air and sunshine all day." Tim & Christine Young, Nature's Harmony Farm

On average, food travels 1,500 miles from farm to fork because our food system is highly centralized. Reliance on a centralized production and distribution system raises concern about the issue of food security and the impacts of the higher amounts of energy and water required to maintain a centralized food system. Conventional agriculture and large scale farming complexes rely heavily on petroleum-based fertilizers. Monoculture, the current paradigm of modern American agriculture which is the practice of growing large amounts of one crop, makes crops more vulnerable to disease and contamination and threatens the supply reliability. As fuel prices soar and clean water becomes increasingly threatened, these indirect costs are being evaluated by both consumers and producers alike.

In Georgia, we face major drought threats year after year as growth and development devour water supply and run-off from pesticides and fertilizers remains the number one source of water pollution in the state of Georgia. In 2006, the United States Geological Survey tested over 186 streams and over 5,000 wells in 51 regions. Every stream sampled contained one or more positive sample for pesticides. In agricultural areas, 97 percent of the samples had one or more pesticides and over 90 percent of fish in farming regions had detectable levels of pesticides.

Growing Green Collar Jobs

As younger generations search for greener jobs, sustainable and organic farming offers an opportunity to make a positive impact on the environment and make a comfortable living. Sustainable farming operates with the understanding that the health of the soil is directly related to the health of the crops and future yields.

Inspiring younger generations to have a role in agriculture becomes more and more important as the average age of a farmer, currently 55, rises and questions abound over

who will grow our food in the future. Young people are not the only ones interested in advancing organic agriculture, however. With the Food and Agriculture Organization of the United Nations estimating that agriculture is responsible for an estimated one-third of global warming and climate change, conventional farmers and second-career individuals are entering sustainable agriculture motivated by a longing to leave a lasting and positive impact on the world.

The return to sun-powered agriculture is also being fueled by concerns over public health and studies such as one released by the Environmental Protection Agency which reports 60 percent of all petroleum-based herbicides and 90 percent of all fungicides used in conventional agriculture are carcinogenic. Sustainable and organic farming has the potential to improve our overall health, protect and preserve our environment, provide a more secure food future for our communities and bolster local economies. Consumers are becoming increasingly aware of these benefits and are voting with their forks.

A Wave of Opportunity

The increase in demand for organic food is fueling a resurgence of small-scale farms around the world. Concerns over obesity, pesticides, hormone use, and protecting the environment are reshaping the way many consumers think about food. Potential dangers in food from overseas sources, as well as the local economic benefits are key issues in the shift in outlook. Stemming from that attitude shift is a market demand that is far outpacing supply. Organic food sales are the fastest growing sector in the food industry, swelling by 18% in 2007. U.S. sales of organic food and beverages have grown from $1 billion in 1990 to an estimated $20 billion in 2007 and are projected to reach an estimated $23 billion in 2008. In the National Restaurant Association's 2007 Restaurant Industry Forecast, chefs ranked organic food as third on the list of the top 20 items of importance for 2007. Most states cannot keep up with this demand and presenting new opportunities for sustainable growers.

In the past 14 years, the number of local farmers' markets nationally has more than doubled from 1,755 to 4,585, according to the U.S. Department of Agriculture's Agricultural Marketing Service. Community-Supported Agriculture subscriptions, a program where consumers purchase shares in local farms and receive fresh, seasonal food, are exploding around the country and here in Georgia serving as a great distribution vehicle for farms as well as an investment opportunity for consumers to guarantee a source for fresh, local foods.

Georgia has benefitted from this growing momentum for local, sustainable agriculture and has enjoyed its part of the excitement and growth.

Georgia's 6-Year Growth	2003	2004	2005	2006	2007	2008	% increase from 2003 to 2008
Producer Only Farmers' Markets	9	12	18	27	51	62	589%
CSA (Community-Supported Agriculture) **programs**	5	8	8	19	25	35	600%
CSA Shareholders	--	--	405	816	1,400	2,874	609%
Certified Organic Producers	10	20	26	33	48	52	420%
Certified Organic Acreage	273	413	665	1,076	1,565	3,081	1,029%
Attendance at the Georgia Organics annual conference	--	150	320	325	465	700	367%

Data compiled by Georgia Organics with support from the Georgia Department of Agriculture.

"There's this idea that farming is dying out as a profession, that it is really hard to make it as a farmer. All you hear about in the media is that big farms are going under – all we can say is that we're doing it. It's working."

Jenny & Chris Jackson, Jenny Jack Farms

A Sustainable Career

The growing market demand, creative options to get crops into the marketplace, the critical lack of supply catalyzing a resurgence of small-scale sustainable farms – all these are shifting the paradigm and yielding exciting opportunities. Farmers now sell at local farmers' markets; run Community-Supported Agriculture programs to support their operations; conduct direct sales to restaurants and institutions seeking local, sustainable food; form cooperative purchasing and sales ventures; and take part in agri-tourism as a

form of eco-tourism. These options provide farmers with diverse and creative income sources that help support their farming enterprise as well as the local economy. In tandem with the financial benefits to the local economy, the local community is strengthened because of all the direct connections to the farmers and good food.

"We have been very lucky to tap into creative and diverse income sources to support our farm. We sell at a local farmer's market, manage a growing CSA program, work with some restaurants, sell at a permanent farm-stand in downtown Atlanta and recently started an on-farm market during the week. We love connecting with the people who will be eating our food – it makes the hard work very worthwhile."

Judith Winfrey & Joe Reynolds, Love is Love Farm, Douglasville, GA

Growing more Growers

The South lags far behind in advancing and supporting sustainable agriculture, yet the opportunities for success are growing steadily. A career in sustainable agriculture provides the chance to have a comprehensive and far-reaching positive impact on our environment, economy, our health and our communities by growing food in a thoughtful and intentional manner. Sustainable agriculture is not just a trend but is a viable and popular option to creatively and sustainably address global climate crisis and water pollution issues.

Dig In!

"One amazing thing in Georgia is that everyone wants to be in contact and share ideas – it's not a closed group. We are truly a community."

Daniel Parson,
Gaia Gardens in Atlanta

Many resources are available to budding and established sustainable farmers in addition to this curriculum. Georgia Organics is proud to provide the following resources:

- Resource-based website featuring a Grower's Exchange virtual community and direct marketing tools
- Farmer mentoring program
- Annual educational conference
- Farmer Network
- Ongoing educational classes for new and transitioning farmers
- Connection to a supportive community that wants to see you succeed

Food is in the critical intersection where health, the environment, and the economy meet. By improving the way food is grown and strengthening the community connection to and relationship with food and local farmers, a shift to a localized, sustainable food system has the potential to reshape the way food is grown, distributed and eaten in America.

INTRODUCTION: How to use the curriculum

This curriculum is designed as an instructors guide. It is intended to give instructors in a variety of settings information on the scientific basis for Organic Farming and Gardening. It can be used in its entirety as a full course or selected sections can be inserted as a supplement to a general course on agriculture or gardening. The design assumes that instructors will have access to curricula that cover general agricultural topics, such as tillage and cultivation equipment and greenhouse management. Information in these areas is limited in this curriculum, to specific organic management techniques which may not be included in existing curricula.

The **Table of Contents** is an overall outline of the curriculum. It lists the **Units** and shows the major breakdown of topics. Within each Unit is another **Outline** of the individual **Topics**. This organization into Topics will allow instructors to customize the course to meet individual needs.

Each unit has a title page which lists all the resources available in the curriculum to teach that unit. Resources include:

Student experiments and activities
Teacher demonstrations
Objectives
Summaries
Videos with focus questions
Power point presentation of each unit
Power point presentations of specific topics
Short power point presentation on soil, pests, and composting for 1-2 hour focused classes

There is also a **lesson plan** which lays out a strategy for incorporating the various curricula elements into a student-focused, interactive experience. These lesson plans can be modified based on the level of student, length of class time or depth of class.

Two types of activities are threaded throughout the curriculum. The Practical Application of Unit 8 is a description of how to set up an organic demonstration plot. Instructions for planning, planting and maintaining the bed are included and can be used as hands-on teaching activities throughout the course. Actual participation in developing an organic bed is important in skill development and long-term retention of the information. Students who practice with the demonstration bed are more likely to try an organic bed, field, or garden on their own.

If the course is being taught on a farm, use the **Farm Activities for Students** for ideas of student tasks related to the topics being taught. These activities are found in the Appendix. Activities that need to be done on a farm may not always coincide with the lesson, but are valuable in the over all experience. Students generally enjoy these activities and for an all day class, a couple of hours of work can bring home the physical nature of the job.

Most units include a short (3-5 minute) case study video of an organic farmer. These videos tell a brief story about each farmer including their marketing strategies, and are spread out among the units to start students thinking about marketing from the very first. Since marketing is often a weak area for many beginning growers, the videos serve as a spring board to sustained discussions about the importance of marketing throughout the course. Marketing can be worked into many of the units, as the type of market will effect many production decisions.

Meeting farmers who are currently engaged in the practice of growing organically can inspire and enlighten students. These opportunities are facilitated by the list of farmers who have agreed to be available to host a farm tour of students of the curriculum or be a guest speaker. Please be respectful of these farmers' time and make arrangements with them in advance. If funds are available, an honorarium is appropriate.

Short videos on organics can be accessed from the Appendix in the **Table of Contents**. There are a variety of videos from a 30 second public service announcement promoting organics to animated organic spoofs on popular movies. The videos can be used to spark discussion at any point in the curriculum.

Feedback from those who use the curriculum is of vital importance to Georgia Organics and we sincerely solicit your opinion. Please send us feedback if you use the curriculum. The **Feedback Form** on the last page can be used to send us information about what you found useful, or not, and any other comments you would like to make. We would like to continue to revise this curriculum and your comments and suggestions will guide us in making it more helpful. You can attach the form to an e-mail, paste into an e-mail, or print and mail the form in.

UNIT 1 – SOIL

I. INTRODUCTION

II. PROPERTIES OF SOIL

A. COMPONENTS OF SOIL

1. Mineral
2. Organic
3. Water
4. Air

B. SOIL PHYSICAL PROPERTIES

1. Soil texture
2. Soil structure

C. FACTORS AFFECTING SOIL PHYSICAL PROPERTIES

1. Organic matter content
2. Soil organisms
3. Soil colloids
4. Tillage
5. Freezing and thawing
6. Water movement

D. APPLICATIONS OF SOIL PHYSICAL PROPERTIES

1. Determination of soil texture
2. Recognizing soil structure

E. HYDROGEN/HYDROXYL CONCENTRATION- pH

III. SOIL BIOLOGY AND ECOSYSTEMS

A. SOIL ECOSYSTEMS

1. Soil life
2. Biodiversity

B. TROPHIC LEVELS

1. Producers
2. Herbivores
3. Predators
4. Higher predators
5. Decomposers

C. SOIL LIFE FUNCTIONS

1. Builds soil structure
2. Disease suppression
3. Improve nitrogen and other nutrient retention
4. Mineralizes nutrients
5. Decomposition of plant toxins
6. Produces plant growth hormones
7. Improves crop quality

IV. SOIL NUTRIENT CYCLES

A. Carbon cycle
B. Nitrogen cycle

V. UNIT SUMMARY

Introduction

The origin of soil is the rocks that cover the surface of the earth. These rocks have varying mineral components. Hence, soils derived from these rocks have varying mineral compositions.

The rocks are broken down by physical, chemical and biological weathering into increasingly smaller particles. An arbitrary classification for these particles was devised based on size. This classification ranges from boulders (very large) to clay particles (very small). The smallest of these – sand, silt and clay – are the mineral components of soil.

Soil particles may remain in place where they are weathered from the rocks (parent material). These soils reflect the mineral make up of the parent material and vary across the surface as the underlying rock types vary.

In some areas, such as flood plains and river deltas, soil particles are transported by streams and deposited. The streams pick up soil particles over large areas and from many different rock types. These are called alluvial soils.

Another major force in forming soil is the movement of massive bodies of ice, or glaciers. Glaciers grind up the rocks on the surface as they move, producing soil particles. When glaciers melt they leave behind soils that are rich in minerals and made up of many different rock types.

Soils also contain living and dead organisms, or organic matter. These organisms create pore spaces in the soil which increases the amount of water and air found in soils. This air and water is important not just for the plants, but also for the soil organisms. A healthy soil ecosystem provides a list of benefits for plants including making nutrients available for up-take by the plant.

Two gas cycles are going on continuously in the soil. The carbon cycle involves the intake of carbon dioxide by the plants, with the release of oxygen and the creation of glucose. The nitrogen cycle depends on soil bacteria to convert free nitrogen from the atmosphere into nitrogen compounds a plant can absorb.

PROPERTIES OF SOIL

OBJECTIVES:

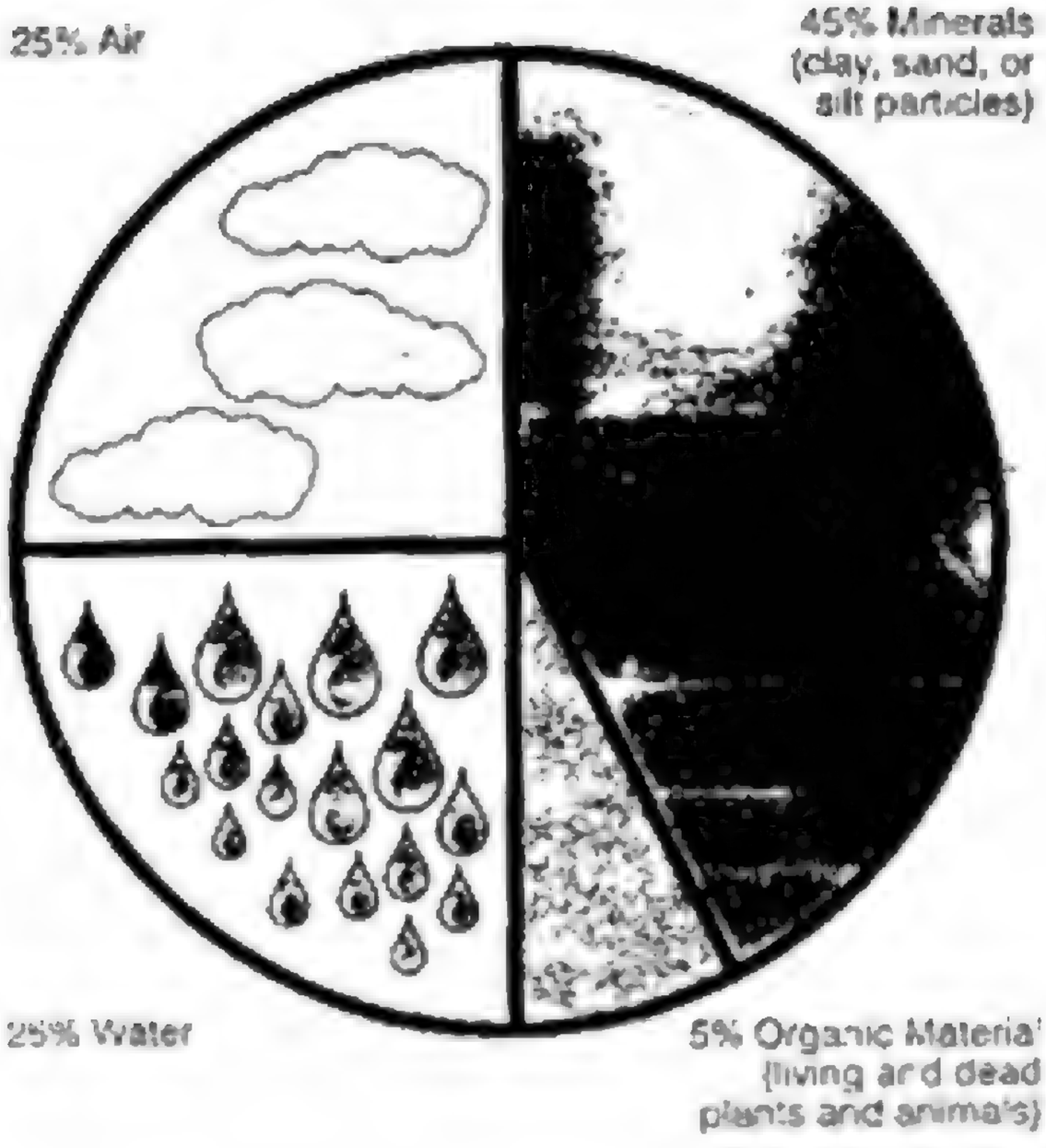
1. Identify six components of soil.

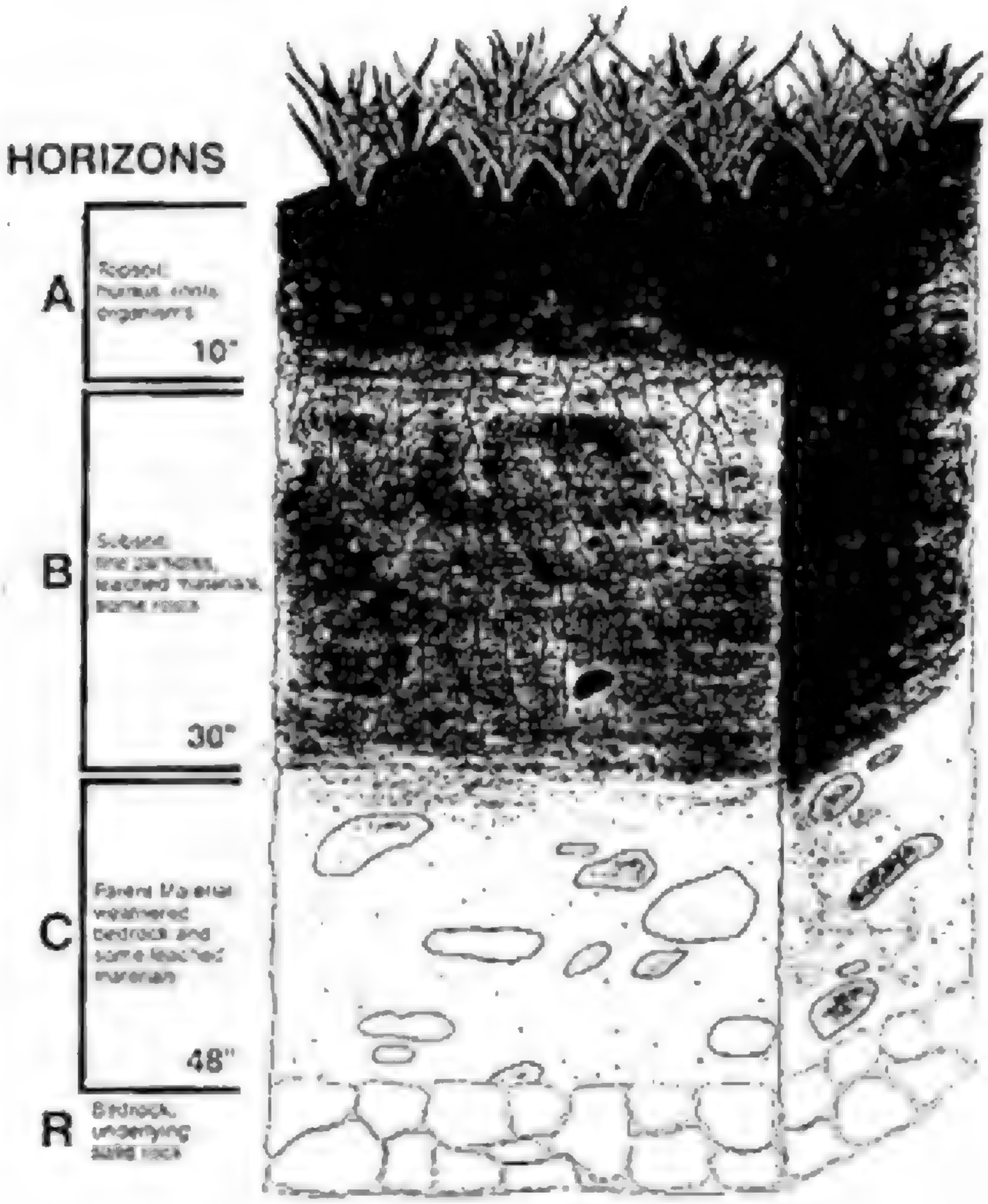
2. Distinguish between the three components that make up organic matter in the soil.

3. Describe the four types of soil texture.
4. Name the factors which have the greatest effect on soil structure.
5. Use the Soil Card to determine soil structure.
6. Explain why organic growing is not as dependent on soil pH as conventional growing.

COMPONENTS OF SOIL

Mineral





7-17. A diagram of a soil profile.

The mineral components of soil are the three smallest rock particles: sand, silt, and clay. These make up 95% or more of the soil solids. The first two, sand and silt, are generally composed of silicon dioxide (quartz). (There are a few exceptions to this, such as, the black mineral sands of Hawaii or the calcium containing sands of the Caribbean.) The reason that most sands and silts are quartz is that silicon is the most abundant mineral on earth after oxygen. It is also the most stable of the common minerals found in rocks. Quartz is more resistant to chemical weathering. Acidic and basic conditions have very little effect on it. That's why we use glass, a product made from quartz, as containers for caustic chemicals. It is also

insoluble. And quartz is not affected by biological or biochemical weathering.

Quartz is also more resistant to physical weathering. It is one of the hardest minerals, so abrasion has less of an effect on it. This means that when water and air move these particles around, other minerals are ground up into very fine particles and carried away by these forces. This leaves the relatively stable quartz particles behind. Sand ranges in size from 2 to .05 mm. Silt ranges from .05 to .002 mm.

The third mineral component of soil is clay. Clay particles are so small individual particles can't be seen without magnification. The structure and minerals of clay are different from sand and silt.

The genesis of clays (how they came to be) is primarily chemical and biochemical. The minerals that are weathered out of the parent material are chemically recombined into more complex chemical and physical structures. The more stable of these form the clays. So, clays are the result of the recombination of the unstable minerals of rocks. Clays vary in composition and structure depending on the types of minerals available and the amount of weathering. Clay particles are less than .002 mm in size.

Most clay particles are formed into plate-like structures composed of very thin layers. This structure allows clays to hold ions between these "plates" and prevent them from being leached by water moving through the soil. This mechanism of holding is called adsorption. Clay particles can also adsorb water between the plates. This is what causes swelling of clay soils.

Organic

The organic component of soil is made up of the soil life and the remains of plant and animal life in various stages of decomposition. All of these together make up the organic matter in soils. Organic matter content is usually 5% or less of total soil solids.

Organic matter is commonly divided into 3 groups:

1. Living organisms
2. Fresh residues
3. Well-decomposed residues or humus

Simply stated, these groups are the living, the recently dead and the "been dead a long time."

The living part of the soil organic matter is made up of a wide variety of creatures of all different sizes. These include bacteria, protozoa, fungi and algae. There are also mobile creatures: microarthropods, nematodes,

flagellates and others. The largest of these are earthworms, arthropods and mites. It even includes the live plant roots. This living portion of the soil makes up about 15% of the soil organic matter. These organisms are constantly feeding on other organisms and giving off wastes, or they are feeding on these wastes and the recently dead organisms and giving off wastes. There is a constant cycle of life, death and feeding going on in the living part of the soil.

Fresh residues or "the recently dead" in or on the soil are dead organisms, plant material, crop residues, dead roots and wastes from organisms. These are the food for the living soil organisms. As the fresh residue is consumed, two things happen: many of the nutrients needed by plants are released and humus is produced.

Humus or the "been dead a long time" is sometimes used to describe the total soil organic matter. It is more properly a word for the dark, relatively stable portion of the soil organic matter. Humus is relatively stable because it is made up of complex molecules that aren't easily broken down by soil organisms and molecules from fresh residue too complex for any organism to break down rapidly.

Humus has a number of characteristics that make it an important part of the soil solids, even though it makes up the smaller portion- 5% or less of the organic matter of most soils. One of these is the ability of humus to hold onto some plant nutrients, preventing them from being leached. Humus can buffer some harmful elements in the soil, such as heavy metals, and prevent plant uptake of these.

Water

Minerals and organic matter together make up 100% of the soil solids. However, when we look at a loam soil in good condition we find that the solids make up only half (50%) of the total volume of the soil. The other 50% of the volume is pore space. This space is macropores, spaces between soil conglomerates, and micropores, spaces inside soil aggregates. Both of these types of pores are where the soil water is held.

Optimally, water fills 20-30% of the pore space, or about one fourth of the total soil volume. During and just after heavy rains or irrigation, water can fill all of the pore spaces.

This porosity of the soil is vital to plant life. Most nonporous soils do not have the capacity to absorb water and hold it for use by the plants. Also, most plant roots can't grow through a nonporous soil.

Air

Soil air takes up the other 50% of the pore space- all the pore space that doesn't contain water. The amount of air in the soil fluctuates depending on the water content. As water moves into the soil from rainfall or irrigation, it fills the pores and forces the air out. As the water drains out of the pores and evaporates at the surface, air is drawn back into the soil. Soil water and air are interrelated. That is, the amount of water moving into or out of the soil determines the amount of pore space for soil air.

SOIL PHYSICAL PROPERTIES

Texture and structure are two terms used to describe the physical properties of soil. Though they are sometimes used interchangeably to describe the same physical characteristics of soil, they are quite different.

Soil Texture

Soil texture is used to describe the relative amounts of sand, silt, and clay that make up the mineral portion of a given soil. This is one aspect of the soil that cannot be altered economically over large areas. Texture in small areas may be changed for specialty crops, such as adding sand to a bed in a clay soil, but soil management has no effect on texture.

Soils that are formed in place from parent rock material generally reflect the content of the rocks from which they were formed. Alluvial soils covering flood plains are subject to addition of new material during floods, but the material deposited is usually the same texture. Glacial soils were formed by past forces and are texturally stable now.

The four common names used to classify soils give an indication of the size of the mineral particles that make it up:

- *Sandy*
- *Silty*
- *Clayey*
- *Loamy.*

Three of these, sandy, silty and clayey contain large amounts of or only those for which they are named. Loamy describes a class of soils that contain a certain percentage of each particle size.

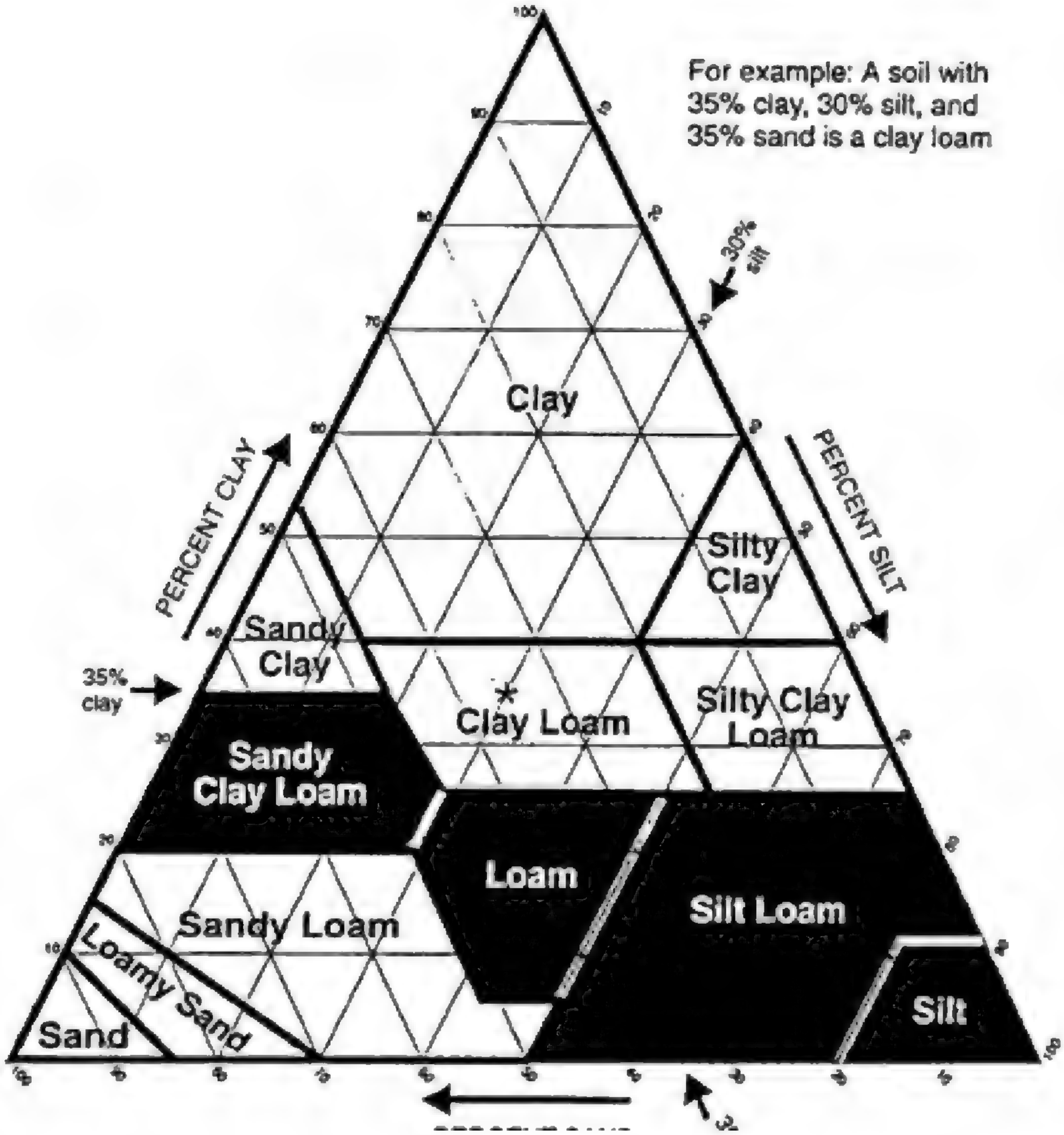
Sandy describes soils that contain at least 70% sand size particles and up to 15% clay particles. These soils have a coarse to moderately coarse texture. Individual sand grains can be seen and sandy soil crumbles when squeezed.

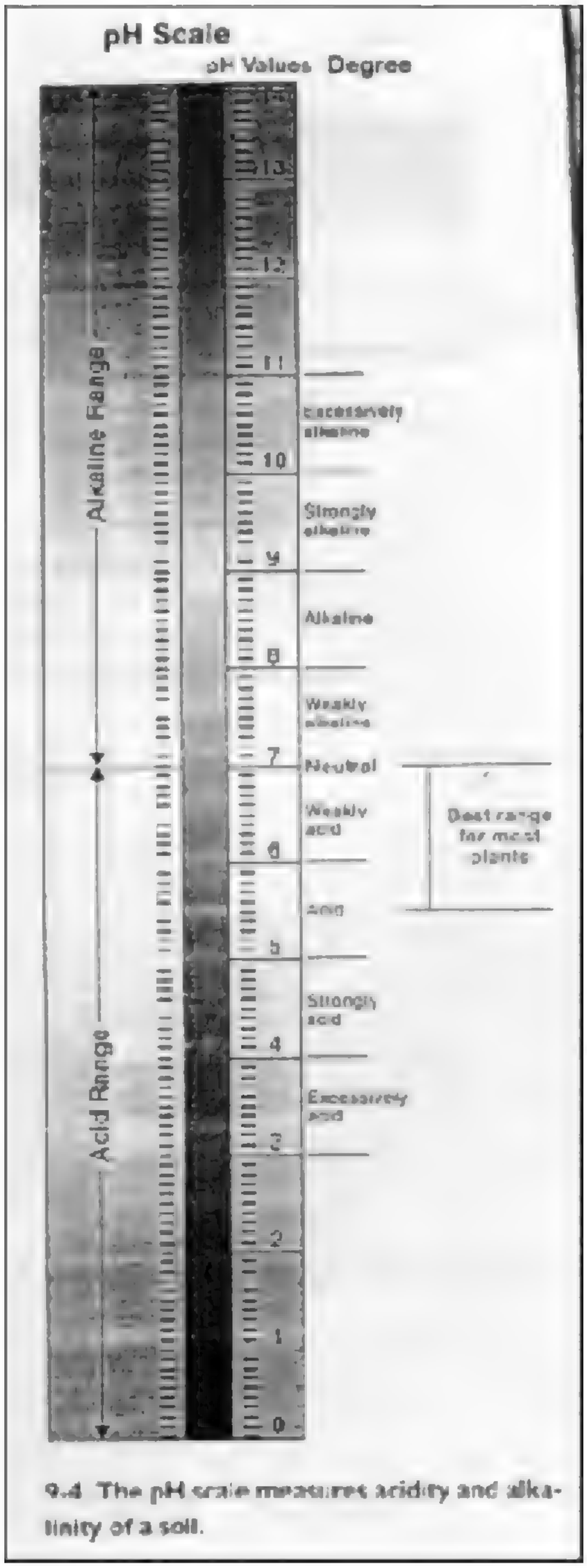
Silty describes soils that contain from 40-100% silt, with sand and/or clay making up the rest of those containing less than 100% silt. These soils have a medium texture. Only the larger of the individual grains can be seen. Silt feels and acts like sand when dry and like clay when wet. Dry silt feels grainy like sand and crumbles easily. Wet silt feels smooth and slippery like clay and tends to smear and stick together.

Clayey describes soil that contains at least 35% clay particles with the rest made up in different combinations of sand and silt. These soils have a fine texture. Individual clay particles cannot be seen without magnification. Clay with any moisture content feels slick and clayey soils don't crumble easily.

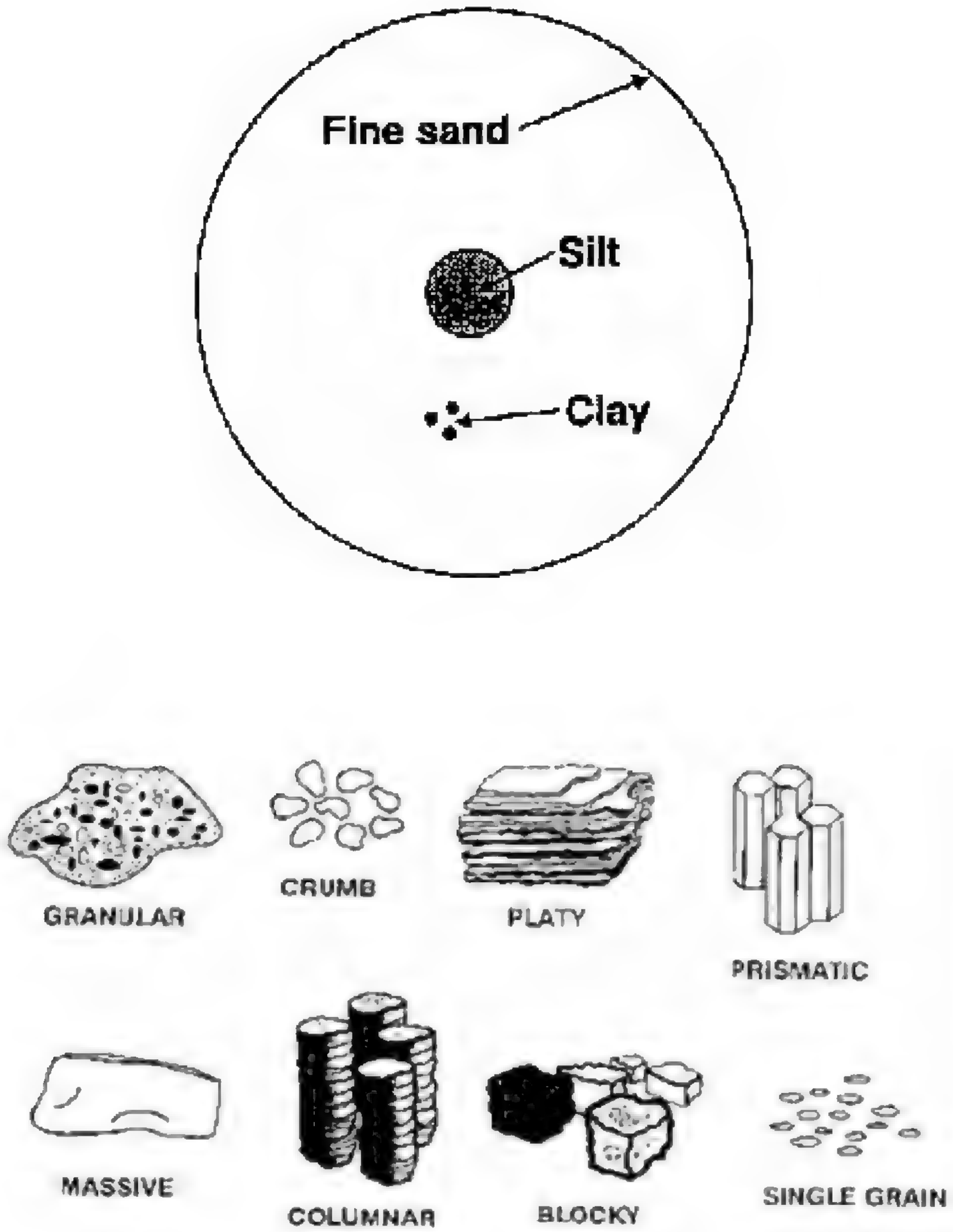
Loamy describes soils with varying amounts of the three soil size particles. These soils have many subdivisions and make up the most complicated soil textural class.

All the different types of loam soils, from Clay Loam to Silt Loam to Loamy Sand, contain from 10-55% clay, from 60-88% silt and from 0-85% sand. However the *Loam Soil* classification itself has a relatively low percentage of clay with sand and silt making up the rest: 7-27% clay, 28-50% silt and 22-52% sand.


For example: A soil with
35% clay, 30% silt, and
35% sand is a clay loam
30% silt
Clay
PERCENT CLAY
PERCENT SILT
Silty Clay
Sandy Clay
35% clay
Clay Loam
Silty Clay Loam
Sandy Clay Loam
Loam
Silt Loam
Sandy Loam
Loamy Sand
Sand
Silt



9.4 The pH scale measures acidity and alkalinity of a soil.



7-15. Soil structure categories.

Soil Textural Classes

Sand	**Dry - Loose and single grained; feels gritty. Moist - will form very easily - crumbled ball. Sand: 85-100%, Silt: 0-15%, Clay: 0-10%**
Loamy Sand	**Dry - Silt and clay may mask sand; feels loose, gritty. Moist - feels gritty; forms easily - crumbled ball; stains fingers slightly. Sand: 70-90%, Silt: 0-3-%, Clay: 0-15%**
Sandy Loam	**Dry - Clods easily broken; sand can be seen and felt. Moist - moderately gritty; forms ball that can stand careful handling; definitely stains fingers. Sand: 43-85%, Silt: 0-50%, Clay: 0-20%**
Loam	**Dry - Clods moderately difficult to break; somewhat gritty. Moist - Neither very gritty nor very smooth; forms a ball; stains fingers. Sand: 23-52%, Silt: 28-50%, Clay: 7-27%**
Silt Loam	**Dry - Clods difficult to break; when pulverized feels smooth, soft and floury, shows fingerprints. Moist - Has smooth or slick buttery feel; stains fingers. Sand: 0-50%, Silt: 50-88%, Clay: 0-27%**
Clay Loam	**Dry - Clods very difficult to break with fingers. Moist - Has slightly gritty feel; stains fingers; ribbons fairly well. Sand: 20-45%, Silt: 15-53%, Clay: 27-40%**
Silty Clay Loam	**Same as above, but very smooth. Sand: 0-20%, Silt: 40-73%, Clay: 27-40%**
Sandy Clay Loam	**Same as for Clay Loam. Sand: 45-80%, Silt: 0-28%, Clay: 20-35%**
Clay	**Dry - Clods cannot be broken with fingers without extreme pressure. Moist - Quite plastic and usually sticky when wet; stains fingers. (A silty clay feels smooth, a sandy clay feels gritty.) Sand: 0-45%, Silt: 0-40%, Clay: 40-100%**

Characteristics of the Various Soil Classes

Characteristics	Sand	Silt	Clay
Looseness	Good	Fair	Poor
Air Space	Good	Fair to Good	Poor
Drainage	Good	Fair to Good	Poor
Tendency to Form Clods	Poor	Fair	Good
Ease of Working	Good	Fair to Good	Poor
Moisture Holding Ability	Poor	Fair to Good	Good
Fertility	Poor	Fair to Good	Fair to Good

Soil Structure

Soil structure is defined as the combination or arrangement of primary soil particles into secondary groupings or arrangements called aggregates or peds. There are small pores or voids within the individual peds (micropores) and there are large pores between the individual peds (macropores). This is the place where almost all of the soil water and air are contained.

If we combine mineral particles, humus and water, then sterilize it, they will remain in the same arrangement. Structure in a soil is an result of activity by the living organisms and plant roots in a soil and their interactions.

There are a number of different types of soil structures. The most common type found in the A Horizon (topsoil) are Spheroidal. Spheroidal structures contain rounded peds or aggregates and are usually loosely associated. This type of structure is common in well-managed pastures and annual crop fields.

Spheroidal structure is broken down into two subtypes: Granular and Crumb. Both of these are characterized by relatively high organic matter content (5% or greater). Granular is a moderately porous spheroidal structure. When a granular structure is very porous, the term crumb structure is applied.

The other types of soil structure are:

- Plate-like (platy)- peds are arranged in relatively thin horizontal plates, usually a product of soil forming processes or parent material.
- Prism-like- vertically oriented or columnar peds, found in poorly drained soils in humid areas and in subsoils in arid and semiarid regions.
- Block-like (blocky)- common in subsoils, particularly in humid regions.

FACTORS AFFECTING SOIL PHYSICAL PROPERTIES

Soils are subject to forces acting on them and these have an effect on their physical properties. As was stated in the section on soil texture, this physical property is not easily or economically altered, except by natural forces which would be catastrophic by cultural and agricultural standards. Soil structure, on the other hand, can be altered by both soil management techniques and natural, non-catastrophic forces. Those having the greatest effect are listed below.

Organic Matter Content

The organic matter content of a soil can be increased or decreased by how it is managed. It can be increased by adding manure or by growing green manure crops and plowing them in. It can be decreased by tillage. This change happens naturally over long periods of time as soil organic matter increases from the accumulation of dead plant and animal residues. When manure or green manure is added the fresh residue or, "recently dead" organic matter increases, then there is an increase in living organisms due to the increase in available food. The relatively stable humus part of soil organic matter increases slowly as a result of these activities.

Soil Organisms

The organisms in the soil will build a structure in non-structured and poorly structured soils, if there are sufficient quantities of air, water, and food. Soil organisms bind individual soil particles together, creating structure.

Most soil bacteria exude a sticky substance onto the outside of their cell walls. This enables them to "glue" themselves to each other and to soil particles and resist being carried down through the soil profile by water moving through the soil. This has the secondary effect of "gluing" two adjacent soil particles together by clusters of bacteria.

Fungal growth in the soil also helps to bind particles together. Fungi grow threadlike structures called mycelia through the soil. These act like a mini root system, binding individual particles together. They also bind individual peds together adding more stability to the structure. Major channels and pores in the soil are opened up by the larger organisms, such as earthworms and arthropods.

Soil Colloids

Soil colloids are organic and inorganic particles in the soil that are very small in size and have a large surface area in relationship to their mass. Colloids have a weak electrical charge, as does water. Soil water binds to these colloids and larger particles, and as water evaporates from the soil, the colloids are drawn closer to each other and the larger particles. This process clusters colloids and larger particles. Continued evaporation draws these particles together into an aggregate.

Tillage

Tillage can have both a positive and negative effect on soil structure. When soil is tilled properly and there is ample food and water present in the soil, soil organisms will build a stable structure relatively fast. This will have a positive effect. When tillage is done improperly or when the soil moisture content is too high or too low, it will have a negative effect on the structure.

Freezing and Thawing

Freezing and thawing have an effect on the soil. When moisture in a soil freezes, it expands and pushes the soil particles and/or peds apart. This increases the pore spaces temporarily. As the soil moisture thaws, the expanded pore spaces tend to remain, opening up the structure.

If you have ever walked across a field after it has just thawed you may have felt this effect. The soil underfoot feels spongy and footprints are more apparent from sinking deeper into the light soil. Gravity, compaction from traffic and water movement through the soil eventually returns the soil close to its original amount of pore space.

Even though freezing and thawing causes only a temporary increase in the pore space in a soil, there is a small positive effect. If the right conditions exist while some of this temporary expansion of pore space exists, the soil organisms will flourish and build a more stable structure, due to the increased amount of oxygen in the soil.

Water Movement

Water movement through soil can have a positive or negative effect on the soil's physical properties. Water soaking into the soil will move vertically. This fills the pore space in the soil and some of this water is stored for use by crops. The negative effect of this movement is that the

water which continues to move through the soil leaches out minerals. Water moving rapidly through a soil that has just been tilled can cause hydraulic slumping- a collapse of the soil structure causing less pore space than before the tillage.

In soils with any clay content, the water moving down through the tillage zone will carry clay particles with it. When it slows down at the bottom of this zone, some of the clay will be deposited. This creates a hard pan or tillage pan. This thin layer of clay stops the water movement the same way that dumping clay into a pond to seal the bottom does.

When water moves horizontally in soils, the usual result is erosion. In a field with shallow tillage, the water moves rapidly down through the tillage zone. When it reaches the bottom of this zone, the water slows down because it cannot soak in as fast through untilled soil. As it accumulates there, the water is forced to move vertically in areas with any slope and carries soil with it.

APPLICATIONS OF SOIL PHYSICAL PROPERTIES

Understanding the physical properties of soils in general is vital to determining soil management practices in any farming system. Soil types (and therefore textures) can vary widely from field to field and even within one field. Management factors can also affect the soil's physical properties. Soil management techniques should vary to reflect this. For instance, the moisture content of a sandy soil should be higher during tillage than a clay soil.

Determination of Soil Texture

Understanding soil texture and knowing the texture of the soil are the most important factors in determining a soil management plan. Determining soil texture can be done by a soil-testing lab. However, these tests can be relatively expensive. Soil textures can be determined using available information. Generalized soil type maps are available in every county Soil Conservation office. These are aerial photographs of the county with soil boundaries superimposed. They also contain a list of all soils represented and their average texture.

Recognizing Soil Structure

Soil structure is not as easy to determine as texture. That's because

structure is dependent on a number of factors which include management, organic matter content and soil biology. The best way to check soil structure is to carefully remove a profile of the topsoil without compacting or breaking it up. This can be inspected visually and compared to photographs of soil, or comparison with other soils, demonstrating different grades of structure.

HYDROGEN/HYDROXYL CONCENTRATION- PH

One of the first chemical tests applied to soils was the pH test. This test measures the relative levels of the hydrogen and hydroxyl ions (H+ & OH-). On the pH scale, when the levels of hydrogen ions are high, the soil is acidic. When the levels of hydroxyl ions are high, the soil is basic.

The pH scale itself is based on a logarithmic scale. One does not have to understand logarithms in order to understand the pH scale. It is important to know that the scale ranges from 0 to 14, with 0 being completely acid to 14 being completely base. A neutral solution is in the middle of the scale- 7. Also, since this is a logarithmic scale, a change of one number means the soil is 10 times more acidic or basic. For example, a change from 6 to 5 means the soil is 10 times more acidic.

The pH of the soil became important as growers began using more chemicals. The salt fertilizers and pesticides had the effect of killing off most of the soil life, inhibiting the natural nutrient cycling by these organisms. With the soil life suppressed, the plant life resorts to absorbing the products of chemical reactions in the soil for nutrients. These reactions are in turn dependent on the soil pH.

In an organic management system, where soil organic matter and soil life is well managed, pH is less critical. This is because the soil life releases plant nutrients into the soil in a form that is readily available to plants. Thus, plants are not as dependent on the products of chemical reactions.

Soil pH is a tool for indicating soil mineral deficiencies and imbalance in organic systems, just as a thermometer measures body temperature. When we have a fever, we know that something is wrong- we're sick but we don't know why we're sick. The same is true for soil pH tests- we know there is a mineral deficiency or imbalance but we don't know what it is.

In the past, pH was only an indicator of relative acidity or alkalinity. As we have learned more about the impact of the mineral content of soil on soil quality and plant nutrition, we have started to use pH in a different way. Rather than using pH to determine how much lime to add to an acidic soil, for instance, we use pH to tell us if further tests for specific minerals are necessary.

SUMMARY

Soil comes from the weathering of rock into the smaller mineral particles of sand, silt, and clay. Sand and silt are generally composed of quartz (silicon dioxide), while clay particles vary in composition depending on the source rock. Living organisms and the remains of plant and animal life make up the organic matter. Though the organic matter of most soils is 5% or less, it is very important in the fertility of the soil. Pore space, the space between the solid particles of the soil is occupied either by water or air. The amount of air will fluctuate with the amount of water in the pore space.

Soil texture is classified by the relative size of the particles which predominate in a particular soil. From largest to smallest particle size, these are sand, silt, and clay. A fourth category, loam, consists of soil with varying amounts of sand, silt, and clay particles. Soil structure is defined by the way the sand, silt, and clay particles are arranged into aggregates or peds.

While soil texture is not easily changed there are a number of forces and management practices that can change soil structure. These are organic matter content, soil organisms, soil colloids, tillage, freezing and thawing, and water movement.

Soil management practices should be based on knowledge of the soil texture and soil structure of the fields to be farmed. Soil maps and an analysis of a profile of the topsoil can provide this information.

pH is a measure of the acidity or alkalinity of a soil. When plants are dependent on chemical fertilizers for nutrition, pH is an important factor because the degree of acidity effects the chemical reactions which release the nutrients. pH is less critical in organic systems since the soil life releases nutrients that plants can absorb.

SOIL BIOLOGY AND ECOSYSTEMS

OBJECTIVES:

1. *Name four types of organisms that are important in the soil ecosystem.*
2. *Define soil biodiversity.*
3. *Identify the five trophic levels in the soil food web.*
4. *Describe five ways the soil food web helps plants.*

SOIL ECOSYSTEMS

Understanding soil ecosystems is the major key to good soil management. In the past, we concentrated on managing only the physical and chemical components of soil, but recent botanical and microbiological research has discovered vast complex soil ecosystems that are necessary to maintain healthy and productive plant life.

This discovery has caused a change in the way we approach agricultural management. In the recent past, the "industrial" model that focused on the farm system in terms of time and material management necessary for product output was used. We're now adopting a "biological" model of management. This includes promoting soil fertility through managing the soil ecosystem.

Soil Life

There are many more individual life forms within the soil than live on the surface of the earth. This includes each individual plant, animal and insect living on the surface. For instance, there can be 1 to 4 **billion** single-celled bacteria per teaspoon of soil, and up to 1 **million** fungi. Soil algae may run as high as 100,000 per teaspoon under favorable conditions.

The microscopic life in the soil includes bacteria, protozoa, some types of fungi and algae. Animal life in the soil includes nematodes, arthropods and larger animals such as rodents, earthworms, ants, snails, spiders, mites and various other worms and insects. The microscopic life forms provide the majority of the benefits to plants.

All of the microscopic life form types contain individual species that perform different functions. We sometimes think of all bacteria as being "bad," or producing disease, but only a very small percentage are disease causing types. The "good" bacteria in the soil perform many functions necessary to support plant life. These include:

- Nitrogen fixing
- Nitrogen cycling
- Protection from harmful fungi
- Recycling dead plants and animals
- Decomposition of plant toxins

Biodiversity

Soil fertility has come to mean having a large number of different types of life forms in the soil, or soil biodiversity. It is necessary to remember that biodiversity alone does not necessarily mean that a soil is fertile enough to produce the intended crop. Different types of crops are dependent on different ecosystems.

Annual field crops require a different ecosystem than woody perennials, for instance. Most vegetables require a bacterial-dominated ecosystem to supply most of their nutrients. Most of these rely on symbiotic fungi for some nutrients, but an assay of soil life where annuals thrive contains far more bacteria than fungi.

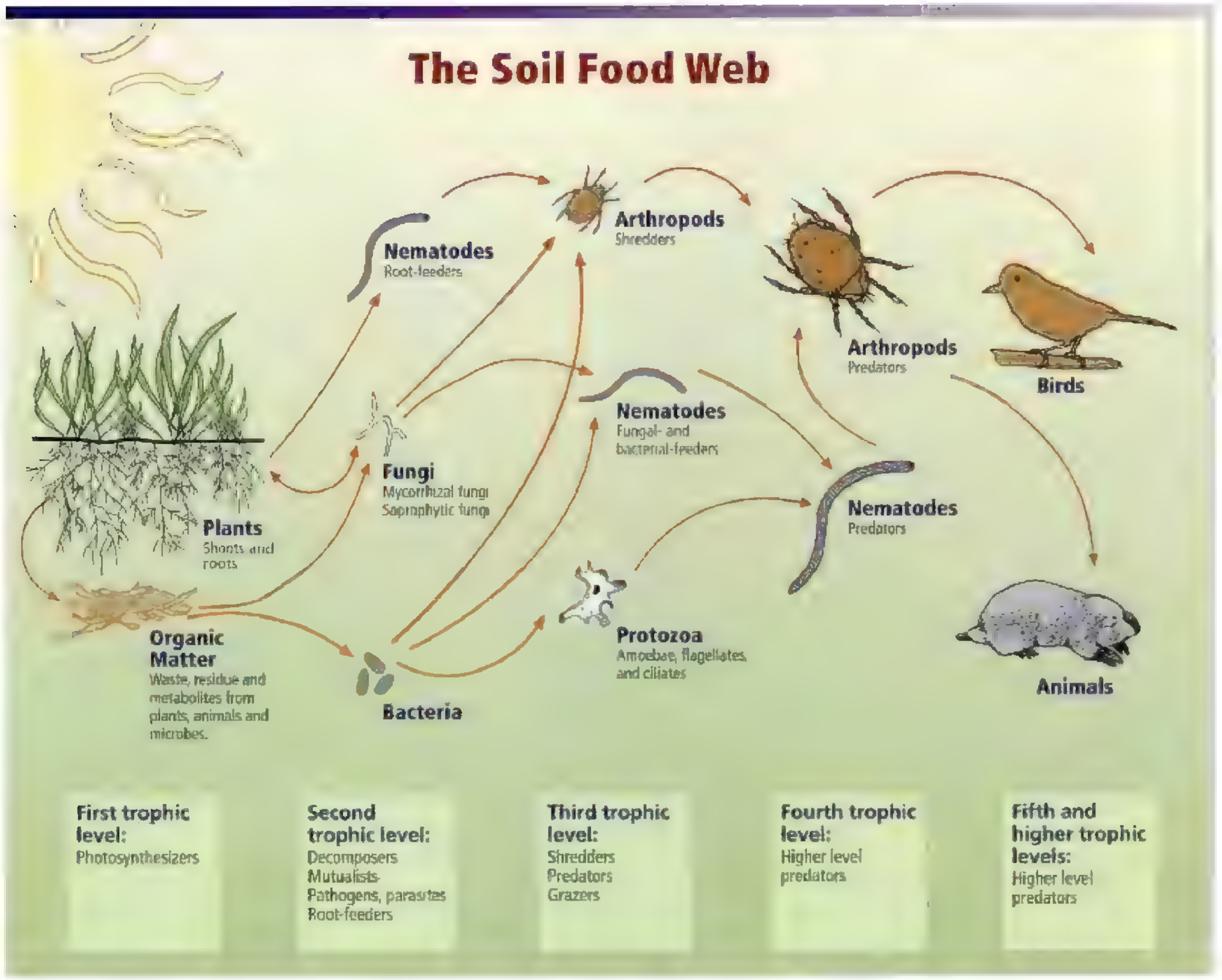
On the other hand, woody perennials like berry bushes require a fungal-dominated soil ecosystem. The predominance of fungi over bacteria is similar to what occurs in forest soils which are their native habitat.

These two types of ecosystems require different management techniques and types of compost to promote the right kind of biodiversity in the soil for the crops. These different management techniques are discussed in Unit 2.

TROPHIC LEVELS

There are many ways of classifying life forms. One of the most common is by what type it is: plant or animal. Then we divide these into different groups, such as bacteria, fungi, nematodes, mites, and so forth. Within these groups in soil ecosystems there is a great diversity of food sources and functions. An example of this is nematodes. They can feed on plants (root knot nematodes), on other life forms (predatory nematodes), on fungi, or on bacteria.

Defining ecosystems by what they eat, or trophic levels, simplifies classification of the individual life forms and gives us more information for management practices. Trophic levels are described from the primary producers (First Trophic Level) to the waste processors (Fifth Trophic Level). The following gives a simplified view of the primary members of these levels.



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Producers

Producers make up the first trophic level. These include all the photosynthesizers, or life forms that produce food from sunlight. We generally think of plants as producers, but the soil contains others, such as blue-green algae. Producers are the source of food for all other trophic levels.

Herbivores

There are two basic groups of soil organisms that feed on the photosynthesizers:

- Plant feeding nematodes- These are plant parasites that burrow into the roots of plants. They feed on the nutrients that the plant makes and transports to the roots.

- Mycorrhizal fungi- These are fungi that grow into the roots of plants and establish a symbiotic relationship with them. They absorb and transport nutrients from the soil to the plant and, in return, the plant feeds them some of the sugar it makes.

Predators

These individuals in the soil eat members of the first and second trophic level. They include the following two main groups:

- Fungal Feeders- This includes fungal-feeding nematodes and mites. They eat the fungal symbionts of plants and the fungal waste feeders.
- Bacterial Feeders- This includes the bacterial-feeding nematodes, flagellates, amoebae and ciliates. They eat all types of bacteria.

Higher Predators

The higher level predators feed on the lower level predators. This group includes predatory nematodes, mites and arthropods.

Decomposers and Waste Processors

Decomposers are the soil life that feeds on dead plant and animal material. They turn the dead material into humus. This group feeds on dead members of all the trophic levels, including their own. Waste Processors feed on the wastes given off by all members of the soil ecosystem. They are responsible for producing many plant nutrients.

Together, these different groups make up what is known as the soil food web. This is a complex and interconnected system which is reliant on each other to flourish. Soil management requires an understanding of these complex relationships.

The first positive management practice is to keep something growing in the soil all the time. Some of the members of the food web are directly dependent on plants to live. Another positive practice is to return plant and animal residue to the soil. This can be done through use of green manure crops, plowing in crop residues, and/or adding compost.

Negative effects, those which kill off soil life, include the use of herbicides. Herbicides are far more effective at killing bacteria than plants.

Removing most of the bacteria from the soil food web restricts the availability of many plant nutrients. Another negative effect is produced from tillage and compaction of soil. These actions destroy the symbiotic fungal colonies that provide the plants with a major portion of nutrients.

SOIL LIFE FUNCTIONS

The soil life food web provides benefits to plants. These benefits are direct, like a symbiotic fungus that supplies the plant with nutrients, and they can be indirect, like a group of waste processors that keep toxins from building up in the soil. The main benefits to plants from the soil food web are:

Builds Soil Structure

With adequate oxygen, moisture and food present in the soil, the soil life will build a stable structure. This structure is porous, allowing rain and irrigation water to soak into the soil instead of pooling and running off. It also allows for a gas exchange with the atmosphere, replenishing the oxygen in the soil needed by the soil life and plant roots.

Pore spaces are created by the burrowing action of relatively large and small sized creatures in the soil. The structure is held together by sticky substances, called polysaccharides, created by the bacteria and fungi in the soil. Fungi are a major force in stabilizing soil structure. They extend hyphae, thread-like growths, through the soil. These hyphae form a vast network of mycelium which holds the soil conglomerates together.

Disease Suppression

A soil that contains a good diversity of life can inhibit disease-causing organisms. This is done passively by beneficial and benign organisms multiplying to occupy all the niches in the soil. This population density helps prevent disease-causing organisms from multiplying. Disease suppression also occurs when different species of soil fungi create antibiotics that kill off specific bacteria, some of which can attack plants.

Beneficial bacteria can also suppress some fungi that attack plants. Japanese research into *fusarium* infection of melon crops demonstrated this point. An area in Japan that grows melons had a widespread crop loss one year. They noticed that one farmer in the area was unaffected. He grew melons the traditional way, by interplanting leeks. Researchers found that a species of bacteria that flourished around the roots of the leeks protected the

melons from the *fusarium*. When the *fusarium* spores started growing, the bacteria consumed the fungal growth until it was completely gone.

Improves nitrogen and other nutrient retention

A large number of organisms in the soil will increase the amount of nutrients it can hold. The physical ability of clay and humus to hold nutrients is limited and the nutrients can be leached out by water moving through the soil.

The organisms in the soil absorb nutrients and retain them inside their cells or bodies. Nutrients are released slowly as the soil life gives off metabolic wastes and nutrient release also happens when they die and are consumed by decomposers or consumed by predators. The decomposers and predators give off excess nutrients that enter the soil food web.

Mineralizes nutrients

Plants can absorb most nutrients in the soil, but can't utilize all of them. The nutrients have to be in a plant available form. The soil life consumes nutrients that are not in a plant available form, metabolizes them and gives them off as waste. Some of these wastes are nutrients in a form that plants can absorb and utilize.

An example of this is the nitrogen cycle in the soil. This is the process where the different bacteria absorb nitrogen compounds in different forms, resulting in the formation of a plant available form- nitrate. The constant absorption, metabolism and release keeps nutrients, even in soluble form, contained in the life cycles in the soil.

Another example is chelation of nutrients by soil organisms. Some metallic ions are unable to be absorbed by plants. Organisms in the soil can absorb these ions and combine them with an organic molecule (chelation). The metallic nutrients are then easily absorbed and used by the plant.

Decomposition of plant toxins

Some of the waste products given off during the consumption of plant and animals are toxic to plants. These include phenols and tannins. With a diverse soil life present, plant toxins created by plant residue processors are absorbed and converted to non-toxic compounds. This prevents a build up of naturally occurring toxins.

Soil life can also break down many toxic agricultural chemicals. This happens naturally when the appropriate organisms that can metabolize the

specific pollutants exist in the soil. Soil has also been remediated by adding the right organism and a food source.

Produces plant growth hormones

Soil life produces some plant growth hormones that plants can absorb. These hormones improve root growth and branching. An example of this is the group of growth hormones called auxins. These hormones stimulate root growth and are present in earthworm castings. Studies have shown that plants will grow a much more extensive root mass when auxins are present in the soil.

Improves crop quality

Improvement in crop quality by soil life is not well studied. Crop quality has been defined in the past as size (large), uniformity and lack of blemishes. Only recently have we started looking at how soil quality affects the taste and nutrient content of food.

The studies that have been done show a link between high nutrient content and high soil life biodiversity. These studies have shown that crops grown in soils with high biodiversity contain more protein, vitamins and minerals. They also contain higher levels of antioxidants, compounds that help protect against cancer and aging.

SUMMARY

The biological elements of the soil ecosystem are being increasingly recognized for the beneficial role they play in soil fertility. Especially important in promoting soil fertility are the microscopic bacteria, fungi, protozoa, and algae. Greater biodiversity of these organisms create greater fertility, but are specific for certain types of crops.

Ecosystems can be organized by classifying the various organisms that feed in the same way together. The first trophic level of **producers** manufacture their food through photosynthesis, and are the source of food for the other tropic levels. The second trophic level is **herbivores**, which eat the producers. The third trophic level is the **predators** which eat the herbivores, and the fourth trophic level is the **higher predators** which eat the predators. **Decomposers**, the fifth trophic level, break down all the dead organisms into humus. The soil food web is made up of <u>all</u> these living organisms.

The soil food web benefits plants in many ways, such as building a stable soil structure, suppressing disease and improving nutrient retention. Nutrients are changed into a form that plants can absorb by organisms in the soil food web. The web decomposes naturally occurring toxins and produces plant growth hormones. Preliminary research shows a link between high soil biodiversity and high nutrient content of the plants.

SOIL NUTRIENT CYCLES

OBJECTIVES:

1. *Explain the importance of carbon and nitrogen for living organisms.*
2. *List three places where carbon is stored on our planet.*
3. *Describe how carbon cycles in plants.*
4. *Describe two ways that atmospheric nitrogen is converted into forms available to plants.*

THE CARBON CYCLE

All life is based on the element carbon. Carbon is the major chemical constituent of organic matter, from fossil fuels to the DNA and RNA that control genetic reproduction in all organisms. Carbon is stored on our planet in the following major sinks:

- organic molecules in living and dead organisms
- organic matter in soils
- the gas carbon dioxide (CO_2) in the atmosphere
- fossil fuels and sedimentary rock deposits such as limestone; and
- dissolved atmospheric carbon dioxide in the oceans and calcium carbonate shells in marine organisms.

Carbon is cycled (altered and stored or released) through different mechanisms. These include respiration by living organisms, burning fossil fuels and wood, and biochemical methods such as marine animals producing shells. To simplify this process, we will only look at the carbon cycle as it relates to plants and soil life.

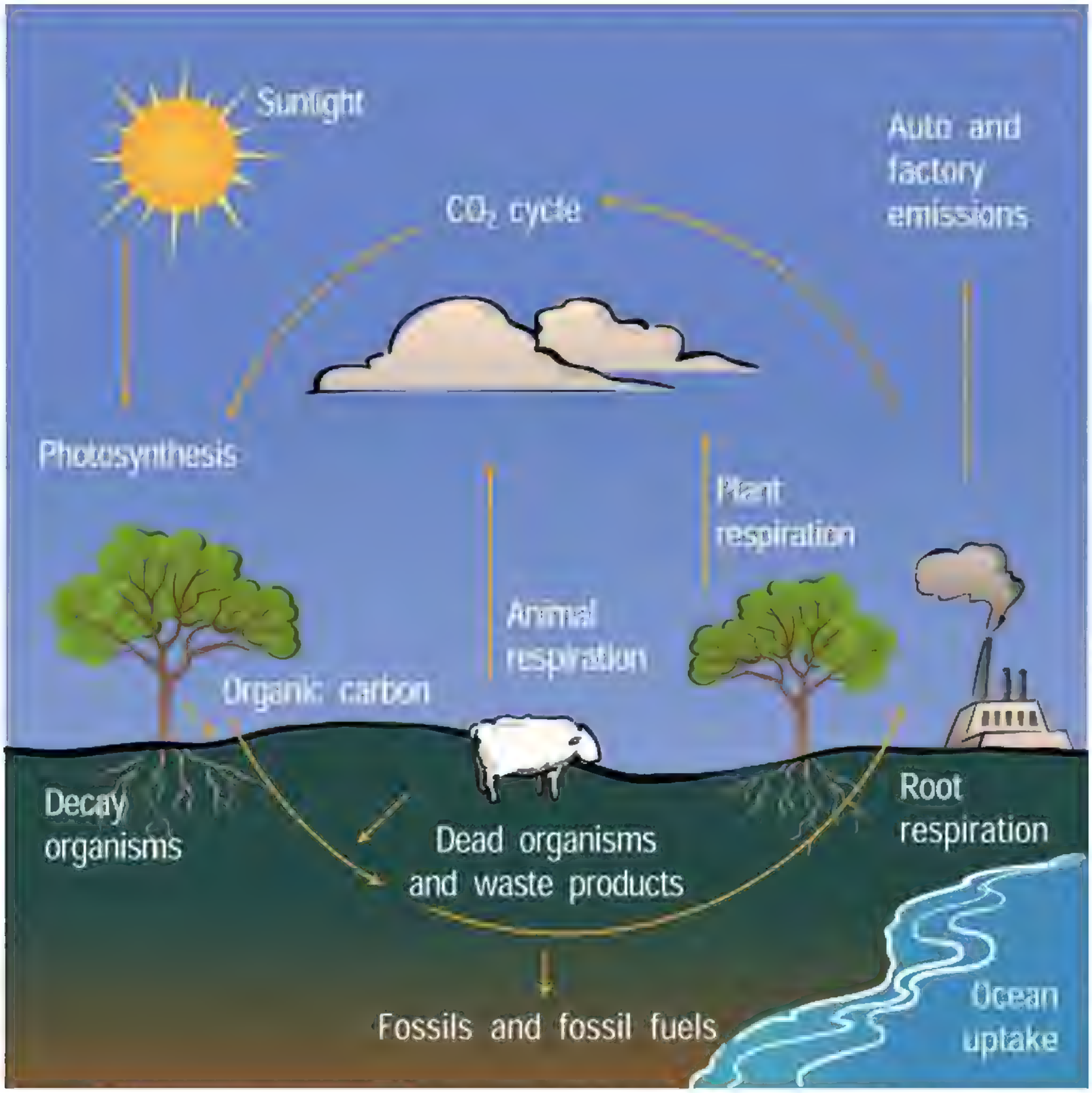
The source of most of the carbon in plants and the soil comes from the atmosphere as CO_2. Plants have the ability to absorb this CO_2 which they can convert to sugars through a process known as photosynthesis. They use the sugar as a food source to grow, produce leaves, stems and roots. When they chemically alter the CO_2, the carbon becomes part of the sugar molecules and the oxygen is released into the atmosphere.

The soil life and animals on the surface continue the cycle. Both of these take advantage of the plants' ability to make food by using the plants as a food source. They do this through symbiotic, mutualistic, parasitic, and predatory relationships. This means that soil and surface life feeds directly on the sugar produced by the plant and/or on the plant itself.

As the plant produces sugar it releases some of it directly in the soil to feed the symbiotic and mutualistic communities of soil life that flourish around the roots. Some of the sugar these organisms absorb is broken down through respiration into CO_2 and released into the soil. The CO_2 in the soil air is eventually released into the atmosphere. Some of the carbon from the sugar is used to build their bodies.

Carbon is also cycled by surface animals in the same way. They consume plants and give off CO_2 into the atmosphere, retaining some carbon for growing. All life (plant and animal) eventually dies and the carbon stored in their bodies returns to the atmosphere as CO_2 or becomes part of the organic matter in the soil.

This organic matter from the decomposition of plant and animal bodies is further processed as food by different organisms and becomes more and more stable as a result. Most of the carbon that enters the soil carbon cycle is captured by the plants and animals or becomes part of the organic matter in the soil. Only a relatively small amount is released back to the atmosphere as CO_2.



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THE NITROGEN CYCLE

Nitrogen is required by all life. It is used to make necessary compounds such as proteins and nucleic acids. Nitrogen (N_2) is also the most abundant element in our atmosphere- it makes up 79% of the atmosphere. But most life can't use it in this form. N_2 is unavailable for use by most organisms because there is a triple bond between the two nitrogen atoms, making the molecule very unreactive.

In order for nitrogen to be used by plants it must be "fixed" (combined) in the form of nitrate (NO_3) or ammonium (NH_4) ions. Animals, in turn, secure their nitrogen (and all other) compounds from plants or from animals that have fed on plants. Nitrogen is converted from N_2 into plant available forms through a biological process called nitrification. Generally, annual field crops use nitrate and woody perennials use ammonium. Nitrification is accomplished mainly in the soil by a number of different microorganisms within the soil ecosystem.

These nitrifying organisms are found in most soils and waters of moderate pH, but are not active in highly acidic soils. They almost always are found as mixed-species communities because some of them (*Nitrosomonas* species) are specialized to convert ammonium to nitrite (NO_2) while others (*Nitrobacter* species) convert nitrite to nitrate (NO_3). In fact, the accumulation of nitrite inhibits *Nitrosomonas*, so it depends on *Nitrobacter* to convert this to nitrate, whereas *Nitrobacter* depends on *Nitrosomonas* to generate nitrite.

The process starts with organisms that absorb N_2 from the atmosphere and break the nitrogen bond in order to use some of it. The waste these organisms give off is ammonia (NH_3). Some of this NH_3 is absorbed by other organisms and is converted to NH_4. This is a source of nitrogen for other organisms that oxidize the ammonium and release nitrites. The nitrites are absorbed and further oxidized by other organisms into NO_3. And this is the form of nitrogen that our annual field crops can use.

In forest soil ecosystems, fungal organisms dominate and there are fewer types of bacteria. The dominant nitrogen cycle in these soils produces ammonium and this is the form of nitrogen that most plants in these ecosystems use.

Another pathway for nitrogen fixation is through plant and bacteria symbiosis. The one most people are familiar with is the rhizobial bacteria associated with legumes. Legume roots absorb certain species of bacteria that have the ability to convert N_2 into another form of nitrogen. The plants isolate these bacteria in root structures called nodules. The legume absorbs N_2 from the soil air through its roots and into the bacteria filled nodules. As the bacteria convert the N_2 into other compounds and give them off as waste, the legume uses enzymes to convert these into nitrate. There are other examples of this type of symbiosis in non-agricultural plants.

The nitrogen cycle can be reversed under certain conditions, converting nitrites and nitrates into gaseous forms of nitrogen which are released into the atmosphere. This process, known as denitrification, reduces the amount of nitrogen in the soil ultimately available to plants.

Denitrification happens under anaerobic conditions, in areas of the soil where gaseous oxygen (O_2) is not available. In the soil, anaerobic bacteria use the oxygen in the NO_2 and NO_3 molecules as an oxygen source and give off N_2. This N_2 is then released from the soil back into the atmosphere.

SUMMARY

Carbon is the major component of organic matter and plants are the source of carbon for all living organisms. Carbon dioxide from the air is absorbed by the plants and, fueled by sunlight, the carbon is rearranged into sugars. These sugars, directly or indirectly, feed all life forms and make possible all life processes. The carbon is returned to the atmosphere through respiration or decomposition of the organic material.

Nitrogen is necessary for life because it is a major component in proteins and nucleic acids. Though nitrogen is abundant in the atmosphere, plants cannot absorb this nitrogen. It must be changed into nitrates or ammonium by microorganisms in the soil. Legumes will absorb the rhizobial bacteria that do this work, so growing legumes is a way to increase the nitrogen content in the soil.

UNIT SUMMARY

The physical components of soil: minerals, organic matter, air and water determine the characteristics of a particular soil. The type of mineral component depends on the type of rock from which it was derived. Soil texture is determined by the relative amounts of sand, silt and clay and is not easily changed. Soil structure is dependent on the way the particles are grouped together and can be influenced by management techniques. The pH of the soil will determine the chemical reactions that can take place in the soil.

Increasingly, soil biology is being recognized as a significant factor in management of soil fertility. Soil microorganisms release nutrients and can be used to provide fertility to the soil, without using chemical fertilizers, which are harmful to the soil microorganisms. For soil organisms to function effectively the soil ecosystem must be functioning effectively. Practices which disturb the soil ecosystem should be used with care.

Both carbon and nitrogen are cycled in the soil ecosystem. This cycling provides a continuous source of both of these essential elements.

LESSON PLANS WITH OBJECTIVES – SOIL

I. AND II. PROPERTIES OF SOIL

OBJECTIVES:

1. Identify six components of soil.
2. Distinguish between the three components that make up organic matter in the soil.
3. Describe the four types of soil texture.
4. Name the factors which have the greatest affect on soil structure.
5. Use the Soil Card to determine soil structure.
6. Explain why organic growing is not as dependent on soil pH as conventional growing.

LESSON PLAN:

1. Show the video of Whippoorwill Farm and discus the focus questions.
2. Use Unit 1 power point presentation Slides 1-19 to present and discuss the properties of soil.
3. If soil tests will be analyzed next class, show the power point presentation from Unit 2 on **Soil Sampling**.
4. Incorporate in class student activities
    a. **Soil Texture Analysis** – may be done outside
    b. Measure pH of soil with pH strips – may be done outside
5. Incorporate in class demonstrations of:
    a. Tray of soil with sand, silt and clay separated
    b. Tray of organic matter with living, dead and well decayed humus separated
    c. Soil type map from Soil Conservation Service for your area
    d. Balls of various sizes to represent the size difference of sand, silt, clay. These may be bbs, marbles, and tennis balls packed in clear tennis ball cans.
    e. Balls of various sizes glued together to represent peds.
6. Outside students activities:
    a. **Soil Texture Analysis** – may be done inside
    b. **Soil Quality Card** to analyze soil
    c. Measure ph of soil with pH strips – may be done inside
    d. **Soil Test** lab may be done with first unit or second unit.

III. SOIL BIOLOGY AND ECOSYSTEMS

OBJECTIVES:

5. Name four types of organisms that are important in the soil ecosystem.
6. Define soil biodiversity.
7. Identify the five trophic levels in the soil food web.
8. Describe five ways the soil food web helps plants.

LESSON PLAN:

1. Use Unit 1 power point presentation slides 20-30 to discuss soil biology, trophic levels and ecosystems.
2. Incorporate in class
    a. **Soil Food Web simulation**
3. Outside student activities
    a. **Collecting Soil Organisms**
    b. Set up **Soil Decomposition** activity for later analysis

IV. SOIL NUTRIENT CYCLES

OBJECTIVES:

5. Explain the importance of carbon and nitrogen for living organisms.
6. List three places where carbon is stored on our planet.
7. Describe how carbon cycles in plants.
8. Describe two ways that atmospheric nitrogen is converted into forms available to plants.

LESSON PLAN:

1. Use Unit 1 power point presentation slides 31-34 to discuss the nitrogen and carbon cycles.

Whippoorwill Hollow Organic Farm – Focus questions

1. List the various marketing strategies that the Byrds' mention.
2. What do the Byrd's grow?
3. What was the best advertisement for the farm?
4. How do people find Whippoorwill Hollow Farm?
5. What is the reward the Byrd's get for their effort?

COLLECTING SOIL ORGANISMS

Purpose – provide method to collect soil organisms.
The organisms will be collected outside and brought inside to observe under a magnifying glass or a dissecting microscope. Equipment needed for each team's collection is a quart-sized container like a cottage cheese container, a two-liter bottle, a piece of screen and some ethyl alcohol or antifreeze. Magnifying glasses or dissecting scopes are useful for identification. An ID sheet for soil organisms would be helpful . Two ways to collect soil organisms are presented.

Procedure A – one week

1. Make a pitfall trap by burying the cottage cheese container up to its lip in the soil.
2. Put about a half-inch of non-toxic antifreeze or ethyl alcohol in the bottom to preserve the specimens.
3. A roof to protect from rain may be arranged with twigs and leaves.
4. In a week collect the specimens that fell into the trap and examine.

Procedure B – 3 days

1. Make a Burlese funnel by cutting the bottom off a two-liter bottle about 1/3 from the bottom.
2. Put half-inch of alcohol or antifreeze in the bottom part of the bottle.
3. Turn the top part of the bottle upside down and place in the bottom part to act as a funnel.
4. Place a piece of ¼ inch rigid wire screen in the funnel.
5. Fill the funnel about half full of soil and place a light bulb over the funnel to drive the organisms down into the alcohol or antifreeze.
6. Leave for about 3 days.
7. Pour the antifreeze and the organisms into a dish to examine.

Various experiment could be set up with this procedure such as comparing the organisms of different types of ecosystems(lawn, woods, gardens) or soil from fields managed with chemical fertilizers and pesticides versus those managed organically.

SOIL FOOD WEB SIMULATION ACTIVITY

Purpose: Identify the soil organisms in the soil, how they are connected to each other and the result of removal of one type of organism.

This activity can be carried out in the classroom. Materials needed are string, cards or paper to write the name of the soil organisms, and some way to fasten the card to the student.

1. Ask students to identify the organisms in the soil. Write them on the board or flip chart. (plants, fungi, bacteria, earthworms, arthropods, nematodes, etc.)
2. Discuss what the organism eats and what might eat it.
3. Have students make a small poster or card for each organism. Let students volunteer to attach a card to their shirt. Each organism should be represented by one student.
4. Starting with the plants, have students name all the organisms that feed or are fed on by the plants. For each connection that the students name, provide a string to connect the student with the plant card on their shirt to each other organism. The students can hold the end of the string in their hand. Go around to each organism. The result should be a web of string connecting the various organisms.
5. Ask the students what would happen if one organism should be removed. Decide on an organism and have that student drop all the strings they are holding. Those organisms on the other end of the string are the ones that will be affected.

Questions:

1. What three organisms in the soil have the most connections to other organisms?
2. Can you think of other organisms which should have been included? If so, what are they?
3. What would be the effect on the soil ecosystem if the earthworms were eliminated from the soil, such as happens with excessive tillage?

UNIT 2 – ORGANIC SOIL MANAGEMENT

I. INTRODUCTION

II. SOIL AIR MANAGEMENT
   1. Primary Soil Gases
   2. Gas Exchange Mechanisms
   3. Managing soil air

III. SOIL WATER MANAGEMENT
   1. Properties of Water
   2. Soil Water Capture and Retrieval
   3. Managing Soil Water

IV. SOIL ORGANIC MATTER MANAGEMENT
   1. Classification of Soil Organic Matter
   2. Soil Organic Matter Levels
   3. Managing Soil Organic Matter

V. SOIL MINERAL MANAGEMENT
   1. Soil Minerals
   2. Soil Mineral Balancing
   3. Managing Soil Minerals

VI. TILLAGE & CULTIVATION
   1. Tillage
   2. Tillage Implements
   3. Cultivation

VII. UNIT SUMMARY

INTRODUCTION

Soil management in any agricultural system is important. Good soil management techniques result in reduced erosion while maintaining or improving crop production potential by increasing the fertility of the soil. The basics of soil management are no different from system to system, but specific applications vary due to differences in soil type, climate and crops. In organic systems, soil management is of primary importance because organic agriculture is dependent on soil organisms to provide plant nutrients and to suppress disease.

The purpose of soil management is to provide an environment where soil organisms can thrive in order to build a stable structure and cycle plant nutrients. In order to do this, we must adequately manage the needs of the soil life.

The factors that can be managed in the soil are:

- Soil Air
- Soil Water
- Soil Organic Matter
- Soil Minerals

Keep in mind that what we are managing is the soil life through this management of the soil and there are positive and negative effects our management practices have on the soil life.

The factors above are listed in the order of the greatest amount of response from plants to the least: soil air management being the greatest, to soil minerals being the least. The plant responses are increased plant health and crop production. This does not mean that one or a few of these factors can be managed and the others ignored. They all work together synergistically to provide an environment for the soil and plant life.

In simpler terms, the soil organisms need the same thing we do to survive and thrive: air, water, and food.

SOIL AIR MANAGEMENT

Objectives:

1. *Name the soil management factor that will result in the greatest positive plant response.*
2. *Give two reasons that it is important to have air in the soil.*

3. *Name the two gases that are of utmost importance in soil management.*
4. *Describe how each of the following factors affect gas exchange in the soil:*

   temperature, rainfall or irrigation, gas diffusion, barometric pressure.
5. *Name the procedures used to manage soil air.*

Managing soil air is the factor that will result in the greatest positive plant response. This is because the soil organisms that produce plant nutrients are aerobic and need to have the oxygen in the soil replenished constantly. The plants also need oxygen present in the soil for nutrient uptake and for root extension.

In soils where gas exchange is not adequate to supply the soil organisms with oxygen, anaerobic organisms flourish. These organisms produce plant toxins. This happens in compacted soils and in soils that become saturated with water and cannot drain.

PRIMARY SOIL GASES

The soil organisms which produce plant nutrients are aerobic life forms. This means they require oxygen to live. These organisms take in oxygen (O_2) and give off carbon dioxide (CO_2) as they feed on organic matter in the soil. These are the two gases we'll look at: CO_2 and O_2. (Nitrogen is also an important gas which enters the soil through this mechanism. See "The Nitrogen Cycle" in Unit 1.3 for additional information.)

CO_2 and O_2 levels in atmospheric and soil air are different. The CO_2 level in the atmosphere is 0.0376% and the O_2 level is approximately 21%. If we measure these levels in a biologically active soil we find that the CO_2 level is 2% to 4% and the O_2 level is 15%.

GAS EXCHANGE MECHANISMS

A gas exchange between the soil air and the atmospheric air is needed to replenish the O_2 content of the soil. In order for this to happen there must be pore spaces in the soil. A soil with good structure contains these pore spaces and there is free exchange of gases between the soil and the atmosphere: O_2 moves into the soil and CO_2 moves out of the soil and into the atmosphere.

This gas exchange is driven by a number of mechanisms:

- Temperature
- Rainfall or Irrigation
- Gas Diffusion
- Barometric Pressure

Temperature

Gases become less dense (expand) as they are heated. This is why hot air balloons rise- the heated gases inside the balloon are less dense (lighter) than the air around it. The more you heat the air inside, the less dense the gases become and the higher the balloon rises. This same mechanism happens in the soil and is driven by heat radiated from the sun. When sunlight hits the soil it raises the temperature, heating the soil air it contains. These gases, which include a relatively high concentration of CO_2, expand and move out of the soil.

The opposite happens during the night as the soil temperature decreases. As the soil cools, the gases in the soil become denser (contract). This creates a slight vacuum pressure in the soil which pulls some atmospheric air in that is higher in O_2 content.

There are two factors which influence this mechanism: the degree of heating of the soil and the water volume in the soil. Degree of heating of the soil refers to how much solar energy it absorbs. This is determined by a soil's color and reflectivity.

A soil that is dark in color will absorb more solar energy than a light colored soil. This is because dark colors absorb heat and light colors reflect it. Dark soils will heat faster and hotter, causing more gas exchange than in a light colored soil.

Rainfall or Irrigation

The water volume contained in a soil will affect how fast a soil gains and loses heat from solar radiation. It takes more energy to heat water than dry soil. This means that the more water there is in the soil, the slower it will heat. Water also holds heat better than soil, so a wet soil cools more slowly.

Soil air occupies the pore spaces in the soil. This is also where water collects in the soil. As water from rainfall or irrigation moves into the soil filling the pore spaces, soil air is forced out into the atmosphere.

Atmospheric air moves into the soil as the water drains through the soil. This creates a small vacuum force that pulls the air in as the water moves down. Evaporation of water out of the soil will also allow atmospheric air to enter the soil, filling the emptying pore spaces.

Gas Diffusion

Another mechanism that causes a gas exchange between the soil and atmosphere is gas diffusion. This is the tendency of gases concentrated in one area to equalize with gases all around. This is one of the natural properties of gases.

There is a higher concentration of CO_2 in the soil and a higher concentration of O_2 in the atmosphere. These gases will disperse to areas of lower concentrations over time.

To illustrate the diffusion of gases, place an open container of only one gas(use a smelly one) in a room. The gas in the container will slowly spread through the room until it is equally dispersed through all the air. The container will have the same mix and concentrations of gases as the room.

Barometric Pressure

Atmospheric pressures are changing constantly. Weather systems have high and low pressures. When a high-pressure system moves in, the pressure forces some O_2 rich atmospheric air into the soil. As a low-pressure system moves in, some of the CO_2 rich soil air comes out into the atmosphere as the pressures equalize.

As these systems move into an area, the atmospheric air pressure changes rapidly. The soil air pressure is slower to respond. This means that there is a pressure difference for a short time until the soil air pressure equalizes with the atmosphere.

MANAGING SOIL AIR

Soil air is managed primarily through tillage. Tillage methods should seek to break up the soil into ped sized conglomerates, creating a physical structure. This allows for gas exchange. In a biologically active soil with adequate food, water and oxygen, the soil life will build a stable soil structure with pore space. Management of soil air is directly dependent on creating and maintaining this structure. The selection of tillage implements, and how and when they are used is critical in creating this physical structure. Avoiding compaction of soils after they have been tilled is another soil air management tool. This is done by limiting traffic in fields and/or through the use of permanent beds where traffic is completely avoided.

The next most important management strategy for soil air concerns soil crusting. Crusting occurs when water drops from rainfall or overhead irrigation strike the soil surface. The energy of the water drops hitting the soil destroys the structure on the surface. When the water evaporates from the surface, it leaves an almost impermeable crust of soil. This crust limits the amount of gas exchange that can happen.

Crusting is managed by surface cultivation. The idea is to cultivate the surface of the soil only as deep as the crust. This can be done with a rake or hoe in small market gardens or with cultivating tines in row crops. It's is not necessary to pulverize the soil into a powder, only to break up the crust into small chunks.

Different techniques can slow or prevent crusting. The most common is mulching. Mulches covering the soil will protect the soil surface from the impact of water on it. They also provide other benefits such as retaining soil moisture and suppressing weeds. By shading the soil, mulches slow down the gas exchange driven by solar radiation, but there is sufficient exchange through the other mechanisms.

SUMMARY

Proper management of soil air will result in the greatest positive plant response of any of the soil management factors. Plants and soil organisms need a constant supply of oxygen to respire and are continually producing carbon dioxide as a waste product. A gas exchange between soil air and atmospheric air is needed to bring oxygen into the soil and push carbon dioxide out. Temperature, rainfall, gas diffusion and barometric pressure will affect the rate of this exchange.

SOIL WATER MANAGEMENT

Objectives:

1. *Explain how the physical structure of water is responsible for the properties of surface tension, capillary action and the ability to dissolve most substances.*
2. *Describe where water is found in the soil and how it moves.*
3. *Name the procedures used to manage soil water.*

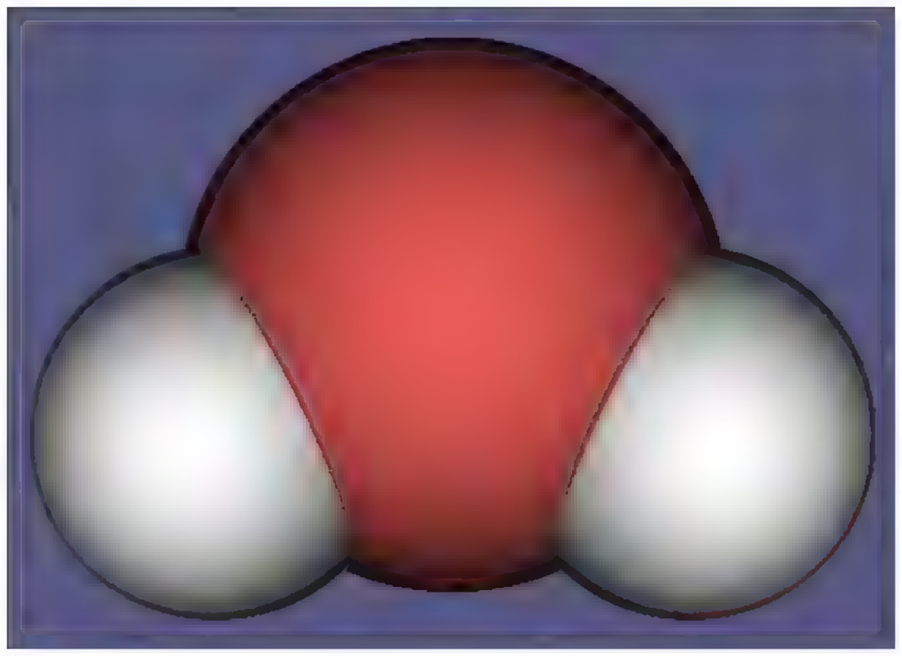
Soil water management is the next most important soil management factor after soil air management. Both soil organisms and plants need water in order to survive. Water is a nutrient for all organisms and it serves other functions. Soil organisms will die if sufficient water isn't available. They will also die if too much is present which occurs in saturated soils that do not drain.

PROPERTIES OF WATER

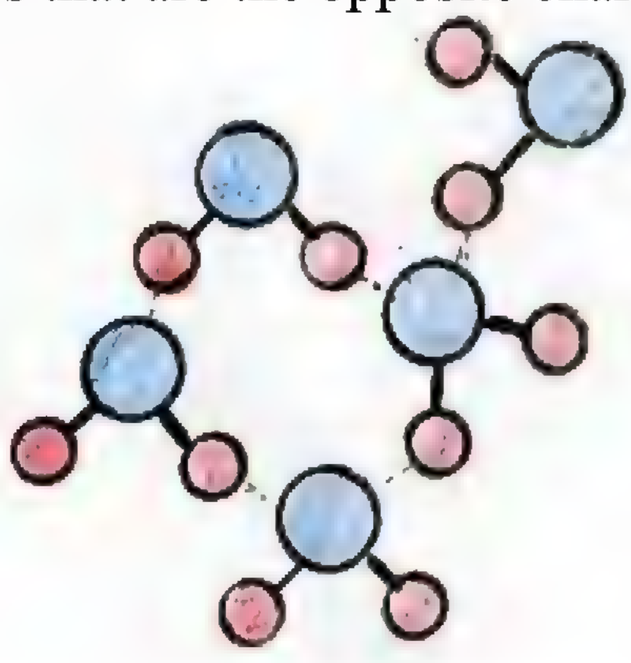
Water (H_2O) has some unique properties. One of these is its ability to dissolve other substances. Water is called "the universal solvent." If it were not for the solvent property of water, life could not exist because water transfers nutrients vital to life in animals and plants. It is also used in all life for nutrient transfer (among other things) within and between the cells.

Water, H_2O, is made up of one atom of oxygen bound to two atoms of hydrogen. The hydrogen atoms are "attached" to one side of the oxygen

atom, resulting in a water molecule having a positive charge on the side where the hydrogen atoms are and a negative charge on the other side where the oxygen atom is. Since water has two electrical charges, it is said to be a dipolar molecule.



These electrical charges allow water to "pick up" mineral ions and carry them. A positively charged ion will be attracted to the negative side of the molecule and a negatively charged ion will be attracted to the positive side. This property is also why salts, such as nitrates, dissolve readily in water. The H_2O molecules can move between the atoms of salts, aligning the sides of the molecules that are the opposite charges.



Another property of water is surface tension. Since opposite electrical charges attract, water molecules tend to attract each other. The side with the hydrogen atoms (positive charge) attracts the oxygen side (negative charge) of a different water molecule. The water molecules are said to have cohesion. This cohesion gives water a surface tension, demonstrated by water spiders "walking on water. It also gives H_2O the property of capillary action. (Capillary action is explained in the next section.)

SOIL WATER CAPTURE AND RETRIEVAL

In order for water to be available to soil organisms and plants, the soil must be able to absorb it. This requires pore spaces that are present in soils that have good structure. As water moves down through the soil profile it "pulls along" more molecules due to its cohesion. This causes the water on the surface to soak into the soil even though all the pore spaces are filled with water just below the surface.

In times of heavy rain or irrigation, it is possible for all the pore spaces in the soil to be filled with water. When this happens, the soil is said to be saturated. When the rain or irrigation ends, water will continue to be pulled down through the soil profile by gravity, leaving behind all the water that the soil has the ability to retain. This volume of water that the soil can retain is called the field capacity. Different soils' field capacity varies depending on their texture, structure and organic matter content.

Some of this water can be retrieved. In other words, it can be pulled back up through the soil profile towards the surface. This happens through a process called capillary action. As the water on the soil surface evaporates, the water molecules below them are pulled up. This is due to the cohesion of the water molecules.

Capillary action happens only within a certain size pore space. If the pores are too large, the "chain" of water becomes too large and too heavy for the capillary force to pull the molecules up. If the pore spaces are too small, capillary action can't happen. Aerobic soil life creates a structure with pore spaces within the size range for capillary action.

This action can be illustrated by placing the corner of a paper towel and a drinking straw into a glass of water. The pore spaces between the fibers of the paper towel are small enough that the water can move up through it, against the force of gravity. The diameter of the straw is too large for capillary action and the water won't move up it.

MANAGING SOIL WATER

The primary soil water management factor is the same as for soil air: creating a physical structure through tillage, and managing soil life so that a stable structure will be built. Soil water management is dependent on the existence of pore space in a soil.

Most substances, including soil, resist water absorption when they are dry. For this reason, soil water should be maintained at a minimum level, at least, to achieve maximum capture of water.

The optimal water content in a soil is between 20 and 30% by volume. This means that about half of the pore spaces in a soil should be filled with

water, leaving the other half for air. Keep in mind that this is an optimal goal; soil water levels will fluctuate with rain or irrigation. The important thing is not to over-irrigate, which deprives the soil life and plant roots of oxygen, or to allow the soil water level to get so low that the soil life begins to die off and the plants are stressed.

One way to monitor the soil water level is by using a moisture meter. This is a device with a probe that is placed in the soil and a meter to give a reading of moisture content. The important things about using a meter are to have a probe long enough to go down through the entire tillage zone and to take a number of readings at different depths.

A simpler way is to do a visual examination of the soil for moisture. A small trench or hole dug to tillage depth can be used to observe moisture content. A fork or spade can be used to remove an intact plug of soil to the tillage depth. This plug can be examined to get a visual idea of how moist the soil is. Structure can be observed at the same time using a plug. Either way, it takes experience in matching these observations with crop response to be able to use this technique.

Your chosen method of measuring soil water content should be performed in multiple places in each field or area. This is because low areas in a relatively flat field will accumulate more water. Where there is a slope, the soils at the bottom of the slope will generally contain more water due to runoff. Also, areas that receive more sunlight will tend to dry out faster.

SUMMARY

The dipolar structure of a water molecule with both positively and negatively charged areas results in its ability to dissolve most substances and stick to itself and other charged surfaces. Water in the soil is found in the pore spaces. Pore spaces may be created by tillage and, then managed by maintaining soil life in order to build a stable soil structure.

SOIL ORGANIC MATTER MANAGEMENT

Objectives

1. *Describe the importance of having organic matter in the soil.*
2. *2. Name the two classes of organisms responsible for production of most plant nutrients.*
3. *Describe three natural factors which tend to decrease and three which tend to increase soil organic matter.*
4. *State the affects of tillage and cover crops on soil organic matter.*

5. *Describe benefits and hazards of spreading raw manure or compost.*

Soil organic matter is the organic fraction of the soil which is made up of plant and animal residues in various stages of decomposition. It also includes the byproducts of the soil life metabolism. Humus is sometimes used synonymously with soil organic matter, but it will be used here to describe the well-decomposed organic material in the soil.

Organic matter in the soil has a large effect on all other factors. It is the food source for the bottom of the food chain in the soil- the decomposers. These individuals feed on dead organisms and their waste products. They produce the stable humus and some of the necessary plant nutrients. Building on this base, a soil's biodiversity can expand and become more complex. As this happens, more plant nutrients are produced and the soil's structure is improved through the actions of the organisms.

Some consider the living organisms as part of the soil organic matter since most of these have relatively short lives, becoming part of the decaying residues in a short time. They are included here because of their importance to soil management.

CLASSIFICATION OF SOIL ORGANIC MATTER

Including the living organisms, we can apply a simple classification to organic matter:

- Living
- Recently dead
- Dead a long time

Living

The greatest number of individual life forms in an agricultural soil used for annual crops is bacteria, followed by fungi. These two classes of organisms are responsible for producing most of the plant nutrients and converting most of the plant and animal residues into more stable humus.

Most soil bacteria exude a sticky coating, made up of polysaccharides, on the outside of their cell walls. This helps to anchor them to soil particles and resist being washed away by water moving down through the soil. It also helps to stick together individual soil particles to form a structure. Bacteria decompose the easily converted carbon molecules found in the dead material, like sugars and carbohydrates.

Fungi decompose the more complex carbon molecules, like lignin that makes up the woody parts of plants. They grow thread-like structures through the soil called hyphae. This aids in stabilizing the soil structure by holding the soil conglomerates together.

This decomposition is the primary stage of organic matter formation. The organic matter in the soil is processed further by soil organisms until what is left in the soil are relatively stable carbon molecules, or humus.

Recently dead

These are the soil microorganisms, earthworms, plant roots, and other organisms that have recently died in or on the soil. It also includes fresh plant materials and manures that are added to the soil. Most of the fresh residue can be recognized by looking at them. These residues contain the basic foods for most soil organisms: sugars, starches, proteins, and amino acids.

Dead a long time

This is the well-decomposed organic material, called humus. It is relatively stable, meaning it is not a food for organisms. Humus is the black material in light colored soils. Most of this is found on the surface of undisturbed soils where plant residues have accumulated and been decomposed.

Humus has a number of properties that help the soil and plant life. It can hold plant nutrients in the soil, allowing plants to absorb them as needed. Humus can also hold many times its weight in water. This helps a sandy soil retain water for use by plants and soil organisms. Its dark color leads to faster warming of soils in the spring, stimulating the soil life, seed sprouting and plant growth.

SOIL ORGANIC MATTER LEVELS

The organic matter level in soils differs due to a number of natural and cultural factors. The natural factors include:

Climate

Climate has the largest effect on organic matter and temperature is the largest climate factor. Areas with high temperatures over long periods, and sufficient rainfall, have relatively lower amounts of soil organic matter. This is due to increased soil life decomposition of residues. This is true even though these conditions stimulate increased plant growth, leading to more available residues.

The other relevant climate factor is amount of rainfall. The level of soil organic matter increases, in general, as the amount of rainfall increases. This is due to increased amounts of plant growth providing more residues and the moisture content of the soil moderating soil temperatures. (Remember from the section on "Soil Water" that it takes more energy to heat water than dry material, meaning that the more moisture in a soil the slower its temperature increases.) This moderating effect slows the soil life activity and more residues are incorporated into the soil.

Soil texture

In general, soils with a heavier texture (clays) tend to have higher organic matter levels than those with a lighter texture (sands). This is partly due to the electrical charges of both clays and humus. The heavier texture slows decomposition by the soil life and helps resist leaching by water moving through the soil. Also, decreased pore space in a clay soil restricts the gas exchange, limiting the amount of oxygen in the soil. This also slows decomposition.

Topography

Slope plays a factor in soil organic matter levels. In general, organic matter levels will be lower the steeper the slope. This is due primarily to erosion. The other factor is drainage. Level areas accumulate more water so decomposition is slower. And level areas at the bottom of slopes accumulate both water runoff and eroded topsoil, resulting in higher organic matter.

Vegetation

The type of plants growing in a soil affects the soil organic matter level. The highest levels of soil organic matter are found in undisturbed grasslands. This is due to the deep, extensive root systems of grasses and

short root life. The decomposition of dead roots rapidly increases the soil organic matter levels.

In forests, the plant residues accumulate on top of the soil, rather than down through the soil as in grasslands. The organic matter levels at the surface of forests soils is very high- up to 50%. However, the organic matter levels within the soil tend to be low- less than 1% to about 4%.

Soil pH

Soils with a pH close to neutral have the ability to decompose more residues. This is due to the effect of acidic and basic conditions on soil life. High concentrations of acids or bases inhibit soil life, lowering decomposition.

Cultural Factors

The cultural factors affecting soil organic matter include tillage, crops and soil amendments. Tillage type and frequency is the largest cultural factor affecting soil organic matter. Tillage practices that break up soil aggregates leave the soil more susceptible to erosion. Frequent tillage not only destroys soil aggregates, it introduces large amounts of oxygen-rich atmospheric air into the soil. This stimulates increased decomposition by the soil life resulting in a decrease of organic matter.

Soil organic matter levels are affected by the type of crops grown and how or if they are harvested. Grass and legume crops tend to help increase soil organic matter. Corn, being a type of grass, leaves a large root system in the soil after harvest. If only the corn is harvested and the stalks left in the field as residue, there is potential for more soil organic matter than if the stalks are removed. Also, cover crops of grass, legumes or a mix of the two increase soil organic matter. They also help resist erosion.

Amending the soil with organic matter from other sources increases soil organic matter. This is done by adding compost and plant residues. (Manure may be added to increase organic matter levels, but the timing of application must be in accordance with organic standards.)

MANAGING SOIL ORGANIC MATTER

Soil organic matter management can be divided into two segments:

- conserving existing organic matter, and
- adding organic matter to soils.

Conserving existing organic matter

The key to the first organic management technique, conservation, is avoiding unnecessary tillage that destroys existing structure and hyper-aerates the soil. When large amounts of atmospheric air are introduced into the soil, the soil life population explodes and feeds on any residue. This results in a dramatic decrease in organic matter.

Another way of conserving organic matter is by retaining crop residue. This means leaving the parts of crop plants that are not harvested in the fields, cornstalks and wheat straw after harvesting the grain. These can be left on the soil surface or incorporated shallowly to help maintain organic matter.

An increase in organic matter can be accomplished through the use of cover crops, either alone or as part of a crop rotation. Cover crops are used alone when fields are not fertile enough to grow high quality food crops. In this case, cover crops are planted a number of times a year and plowed into the soil when they are blooming but before seed formation starts. The types of plants used are determined by the climactic area and the season of the year. (Contact your County Extension office for a list of cover crops suitable for your area.)

To increase organic matter levels in the soil using cover crops requires planting a number of them per season over at least one year. Soil organic matter can be maintained, however, with as little as one grass cover crop per season.

As part of a rotation, cover crops are used when fields would normally be fallow. Cover crops are usually planted in the fall in areas where plant growth is slow or stops during winter. These are plowed into the soil in the spring before planting. (Techniques for incorporation of cover crops are covered below in the section "Tillage & Cultivation.")

Adding Organic Matter

Adding organic matter from sources outside the field is another way of increasing soil organic matter. Traditionally, farmers have spread raw manure mixed with bedding on fields prior to planting. This provides both

organic residue and nitrogen. Recent research has shown that this can be a source of pollution and crop contamination. Runoff and leaching into groundwater of soluble salts from fresh manure is a possible source of pollution. Bacterial contamination of crops from fresh manure is also a possibility.

For these reasons, spreading raw manure is restricted in organic operations. However, the Organic Standards list some exceptions to this. The standards state that raw animal manure must be composted before spreading on a field unless it is:

(i) Applied to land used for a crop not intended for human consumption;

(ii) Incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles; or

(iii) Incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles

Adding manure and plant material after it has been composted is another way to add organic matter. This involves learning a new skill, composting, but has the advantage of not having the long lead time between application and harvest.

Advantages and Disadvantages

There are advantages and disadvantages to each method of increasing soil organic matter. The advantages of cover crops are that they can be used in large areas and do not require learning new skills. Cover crops usually require little management during their development. However, they do require irrigation in extreme conditions to be of benefit. And they require equipment to kill and incorporate them into the soil.

Another disadvantage with using cover crops is that crops cannot be planted immediately after plowing them in. This is because the addition of fresh material containing large amounts of easily available foods (sugars and carbohydrates), combined with abundant oxygen from plowing creates conditions for a soil life population explosion. The soil life can out-compete the plants for nitrogen. The microbes absorb and use the available nitrogen in the soil, creating an artificial nitrogen shortage. (The nitrogen is still in

the soil, contained in the microbes, but it's not available to the plants. This is sometimes referred to as the nitrogen being "tied up.")

Once the readily available foods are used up, the microbes begin dying off and the nitrogen is released back into the soil and enters the nitrogen cycle. As nitrates are released in this cycle, it becomes available again to the plants. This process takes an average of two weeks in warm soils. This means that there is an average two-week wait between incorporation of cover crops and planting or transplanting.

The advantage of adding raw manure directly to fields is that it can be spread as accumulated rather than stored. It requires no composting management time or skills. The disadvantages of using raw manure are listed in the organic standards. This means that if you spread raw manure on the soil surface, you can only use the field for something like pasture or animal feed production. If raw manure is plowed in, there must be 90 to 120 days between incorporation and harvest, depending on the crop. For example, root crops - 120 days; fruit crops - 90 days.

Composting

Composting manure and/or plant material has the advantage of removing the top growth of cover crops from an area and planting right after cultivation. These are composted and spread at any time. It also allows for using composting materials from different sources, like manure, crop residue, fresh residue and off-farm materials.

The main disadvantage is that composting requires some skill and experience, as well as time for management. It also means the possible expense of specialized equipment in large operations. Another disadvantage may be having enough sources of material to compost. If there is not sufficient area to grow plant material outside cropping areas, or if there are not enough animals to supply a sufficient amount of manure, composting materials must be sourced from off-farm. This means time and expense of locating and transporting the material.

Maintaining soil organic matter levels requires the addition of 4 cubic feet of compost per 100 square feet of bed or 64 cubic yards per acre of field per season, on average. Increasing organic matter using compost requires adding compost to the soil at higher rates. This is usually done by adding compost to beds or fields after the initial tillage, mixing it in the top 4-6 inches and adding more to the surface.

In areas that have been managed so that the soil life has built a good structure, all compost should be added to the surface. This can be done once per season to maintain organic matter levels, or before each crop is planted to increase it. Adding compost to the surface has a number of advantages over mixing it into the soil. These include avoiding destruction of the structure near the surface, placing the compost where most of the soil life is concentrated, providing mulch and stimulating faster and higher percentage of germination of seeds.

SUMMARY

The organic matter in the soil is important because it is the food source for the decomposers, mainly bacteria and fungi. These organisms produce most of the plant nutrients and turn the organic matter into stable humus. Natural factors which may result in greater organic matter are increased rainfall, soils with a heavier texture and a level topography. High temperatures, light soils and soils on a slope will tend to have less organic matter. To maintain good soil structure unnecessary tillage should be avoided. Cover crops, especially of the grasses (rye, corn, wheat, etc.) will increase organic matter because of their extensive root system. Raw manure can be added to soil to increase the organic matter but it may lead to pollution and crop contamination. It also limits an organic farmer in what can be grown in that soil for a period of time. Compost can also increase organic matter when added to soil, but it requires skill, materials, and labor to produce the amount needed for a positive effect.

SOIL MINERAL MANAGEMENT

Objectives:

1. *State two reasons mineral management is especially important in the southeast US.*
2. *List the three categories of soil minerals.*
3. *Name the primary procedure for managing soil minerals.*
4. *Describe how to take a soil sample.*

Managing soil minerals has the least effect on plant response, as far as better crop production is concerned. However, good soil mineral management leads to better plant health, higher nutritional quality and increased flavor and shelf life. Good management also avoids conditions where too much of a mineral is added to the point that plants are adversely

affected. The benefits of good mineral management have not been well studied, but recent scientific studies have shown its importance.

Mineral management is especially important in the southeastern United States. This is because we have, for the most part, soils that have been depleted of minerals. (Exceptions to this are soils that have been remineralized by fault movements and soils in flood plains that are remineralized by deposition of mineral rich material.) This depletion is because of higher temperatures and long seasons when the soil is warm which lead to a high rate of biochemical and chemical reactions in the soil, altering the minerals to a soluble form. High amounts of rainfall have leached minerals in this soluble form as ions, as the rainwater moved through the soil.

Remineralizing the soil is necessary in soils like we have in the southeast to insure that plants receive the proper nutrients. Work done by soil scientists have pointed to the need to create a balance of the soil minerals. This balance is surprisingly close to the one needed by animals for good nutrition. These include the proper balance of macronutrients like the calcium-magnesium balance and the proper amounts of micronutrients like boron.

SOIL MINERALS

There are 12 minerals that are considered major plant nutrients. These are usually listed on a soil test under categories called cations, anions and trace minerals. Cations are minerals that form positively charged ions and anions are minerals that form negatively charged ions. Minerals that plants need only a small quantity of are called trace minerals.

The cations that are essential plant nutrients are calcium, magnesium, and potassium; essential anions are nitrogen, phosphorous, and sulfur. Even though they're called "trace" and plants only need a small amount of them, the trace minerals are essential for good plant growth and health. These are zinc, manganese, iron, copper, boron, and molybdenum. All of these minerals are sources of nutrition for the soil and plant life. Some of them function to aid in the physical development of soil structure.

The 12 Essential Soil Minerals

Cations +	**Anions -**	**Trace minerals**
Calcium	Nitrogen	Zinc Copper
Magnesium	Phosphorus	Manganese Boron
Potassium	Sulfur	Molybdenum Iron

SOIL MINERAL BALANCING

Soil minerals are said to be in balance when there is an adequate amount of all the 12 major minerals present in the soil, but not too much of any one mineral to the point that it would negatively affect the crops. These amounts have been calculated through field tests and by measuring nutrient uptake of crops.

When too much of a mineral is added to the soil it can have an adverse affect on the crop. An example of this is adding too much lime. If there is too much calcium in the soil, it restricts most plants' ability to absorb iron. The iron deficiency in the plant will show as a lack of green pigment and the plant will be yellow. (This can be confused with low nitrogen content.)

This is not as much of a problem as adding too much of a trace mineral, since it is relatively easy to remove lime (calcium carbonate) from the soil. Adding too much boron, for example, is easy to do because relatively small amounts can restrict plant growth. Soil testing should be done in order to identify how much of each mineral are present in the soil before adding any more.

MANAGING SOIL MINERALS

The primary tool for managing soil minerals is a comprehensive soil test. Basic tests that measure pH, nitrogen, phosphorous, and potassium (NPK) levels are only useful for spot checks. A comprehensive test should include pH, organic matter level and levels of all 12 major plant minerals.

The next thing that is needed is an analysis of this information to determine if the soil needs any of these minerals added, and if so, how much of which ones. This requires specialized training in soil science and chemistry. Most farmers rely on a consultant for lab tests, analysis and recommendations. Choosing this consultant should be done on the basis of recommendations from others who have used their services and if they are knowledgeable about mineral balancing. They should also be familiar with which amendments are approved by the National Organic Standards Board (NOSB) for use by organic certified farms

To do a soil test, samples need to be taken. This is usually done by the farmer and requires some care in order to get accurate results. The main thing is to use clean, stainless steel or non-metallic tools. Most Soil Conservation offices have stainless steel soil sampling probes they will loan out. A clean plastic bucket can be used to hold the samples.

Samples should be taken at regular intervals around the whole field, or from each bed in the case of bed cultivation. These samples are mixed

together and a composite sample is used to send to the lab or consultant. It's important not to take samples from areas where a concentration of minerals or organic matter has occurred. These are areas near fences and culverts or areas where compost or manure has been stored.

It's important to supply the person making recommendations with as much information as possible about previous management practices. This will help them to better understand the test results and to guide you in managing the soil minerals.

Once the lab work is done and the existing levels of minerals are known, the consultant will send a list of which mineral amendments and how much of each to apply. These are added by spreading them evenly over the area being amended. "Bulking up" can be used to assure even distribution for amendments that are added in small amounts, This technique calls for mixing small amounts of the amendment with something of similar grain size. For instance, a small amount of copper sulfate powder can be mixed with lime (if both these are needed) and then spread.

The mineral amendments should be spread and then immediately mixed into the soil before they are washed away by rain or blown away by wind. Mixing is done by tilling the amendments into the top 4-6 inches of soil. This can be done at the same time as tillage is done for another reason, such as tilling in a cover crop.

The mineral content of the soil should be regularly monitored because leaching and removal by crops reduces the amount of minerals in the soil. Most consultants who work with organic farmers recommend that soil tests be done only once a year. There are some extreme cases where a consultant may want to test the soil more frequently.

SUMMARY

A long growing season with plentiful rainfall results in a long season of soil activity which has led to the depletion of soil minerals in much of the southeast USA. The minerals considered to be major plant nutrients are divided into three groups. Cations (+charged ions) are calcium, magnesium, and potassium. Anions (-charged ions) are nitrogen, phosphorus, and sulfur. Trace minerals are essential but are needed only in small amounts. A soil test is an important tool in managing soil minerals, but following proper procedures is important for getting accurate soil test results.

TILLAGE & CULTIVATION

Objectives:

1. State the primary purpose of tillage.
2. Describe why soil layers should not be mixed.
3. List optimum conditions for tillage of clay soils and optimum conditions for sandy soils.
4. List three types of tillage equipment and an advantage and disadvantage of each.
5. State three reasons to cultivate.

Tillage and cultivation are terms that are used to describe various actions. Here, **tillage** will be used in the sense of primary tillage: the mechanical manipulation of the soil profile to incorporate air spaces. This is done at various depths, the minimum being 4-6 inches. Subsoiling is also a form of tillage. This is the technique of loosening the soil beneath the tilled area to improve drainage and root penetration.

Cultivation will be used in the sense of secondary tillage: shallow tillage operations performed to create soil conditions conducive to improved aeration, infiltration, and water conservation, or to control weeds. This is done as shallow as possible, usually less than 1 inch deep. The depth is determined by the minimum needed to perform the cultivation.

TILLAGE

The primary purpose of tillage is to incorporate air into the soil. This is done by tillage methods that break up compacted soil into ped-sized conglomerates, giving the soil an open, physical structure with air spaces between the peds. A visual model of this is like a jar of marbles- each marble touches other marbles around it and there are air spaces between them. This physical structure gives the soil life the right conditions to thrive: air spaces to allow for gas exchange and water capture and storage.

Another important factor of tillage is to avoid mixing or inverting the soil layers. Implements like turning plows and rotary tillers will mix topsoil with subsoil if set too deep (below the topsoil). This results in immediately lowering the organic matter content of the soil by dilution. For example, when topsoil that is 5 inches thick with 4% organic is tilled to a depth of 10 inches, the resulting organic matter content of the top 10 inches will be around 2%. (This organic matter content will be further lowered due to increased soil life metabolism in response to increased soil oxygen levels.)

Using a turning plow in the same case, the topsoil will be buried under 5 inches of subsoil. This will cause anaerobic conditions in the buried topsoil and will leave low organic matter subsoil to plant in.

Plant growth and production of the first crop will be limited in both cases. These limitations can be overcome with time, given good soil management practices -- addition of organic matter and maintaining soil moisture at optimal levels.

It should be remembered that tillage is used only when necessary. Otherwise it will destroy the existing stable structure that has been created by the soil life, cause a rapid decrease in organic matter and inhibit plant growth. Determining if tillage is necessary is done by direct observation of the soil structure. This is done by removing a plug of soil with a spade or fork and identifying how good the structure is.

Timing of tillage is determined by soil moisture content, soil type and climate. Soil moisture is the most important factor in deciding when to till. Tilling a clay soil that is too wet will result in large, hard clods that resemble pottery. This happens when the clay is smeared and then dries out. Tilling a clay soil that is too dry is more difficult and may strain the equipment.

Sandy and silty soils, which contain no or very little clay, are the opposite. They should be tilled when moisture content is high. This will allow the soil particles to stick together better and break up into peds. Tilling a coarse soil when it is too dry results in "powdering" of the soil. This means that the individual soil particles are separated and no physical structure is achieved.

Climate enters into the tillage equation in the Southeast where there is a combination of sandy soils and high temperatures combined with long growing seasons. In these conditions, tillage should be avoided because it will destroy any structure and speed up organic matter loss. Soil preparation should be surface cultivation only in order to kill weeds or cover crops and incorporate most of the plant material into the soil.

Optimum Tillage Conditions

Clay soil	Sandy soil
Soil moisture – LOW	Soil moisture - HIGH

IMPLEMENTS

Tillage which breaks up poorly structured soil and doesn't mix or invert soil layers can be accomplished with several different tillage implements. Choosing which one to use is a matter of personal preference and matching tillage implements to existing equipment. The variables are

horsepower, power take-off, the type of hitch, and tractor ground speed. The main types of tillage implements are chisel plows, spading machines and subsoilers. Hand tillage methods can be used in small operations.

Chisel plows are individual, curved shanks with replaceable tips. These are long enough to till to a depth up to 12 inches. They are spaced on a bar from 9 to 12 inches apart and can be ganged in numbers equal to the bar width or the horsepower of the tractor. Tractor requirements for chisels are matching hitches, rear hydraulics to raise and lower to desired depth, and 10 to 15 horsepower per chisel (depending on type of soil and tillage depth).

Higher horsepower is required because the tillage action of chisels is dependent on higher ground speed. In order for the action of the chisels to break up the soil into peds, chiseling must be done between 5 and 8 mph. (Speed is dependent on soil type.)

One of the advantages of a chisel plow is cost. These are relatively inexpensive and can be adapted to most tractors and hitches. They are also mechanically simple and require very little maintenance such as replacing worn tips. The only factors that have to be controlled in running a chisel plow is spacing, depth and speed. Another advantage is the ease of attachment and removal. The disadvantages are the requirement of higher horsepower and lower incorporation of cover crop or crop residue.

Spading machines are tillage implements that require power take-off. They are a series of small spades that rotate on eccentric shafts with the same action as a person spading. The main tractor requirements are power take-off, matching hitches, rear hydraulics and a low-speed transmission. The lowest speed requirement is at least ¼ or ½ mph, depending on soil type and condition.

One advantage of a spading machine is excellent incorporation of cover crops. The spades cut up and mix in the plant material for faster break down. The other advantage is more control over ped size and consistency. This is done by varying the ratio of ground speed to power takeoff (PTO) speed. The main disadvantage is the tendency to mix soil layers when used frequently or too deep. Other disadvantages are higher cost, time required for attachment and removal and the time and expense of maintenance.

Subsoilers are used to increase the depth of water infiltration and root extension below the tillage zone or when a tillage pan develops. A tillage pan is an impenetrable layer of soil. Tillage pans develop in two ways. The first is in row cropped areas where tillage is done at the same depth. In these areas, the soil below the tillage zone is compacted by traffic and never broken up. In both fields and beds where the soil has clay content, a tillage pan develops. This is a result of water moving rapidly through the tilled area

and carrying clay particles with it. When it hits the bottom of the tillage zone, the water slows down and the clay is deposited at this depth forming an impenetrable layer. (Just like putting clay in a pond to seal the bottom.)

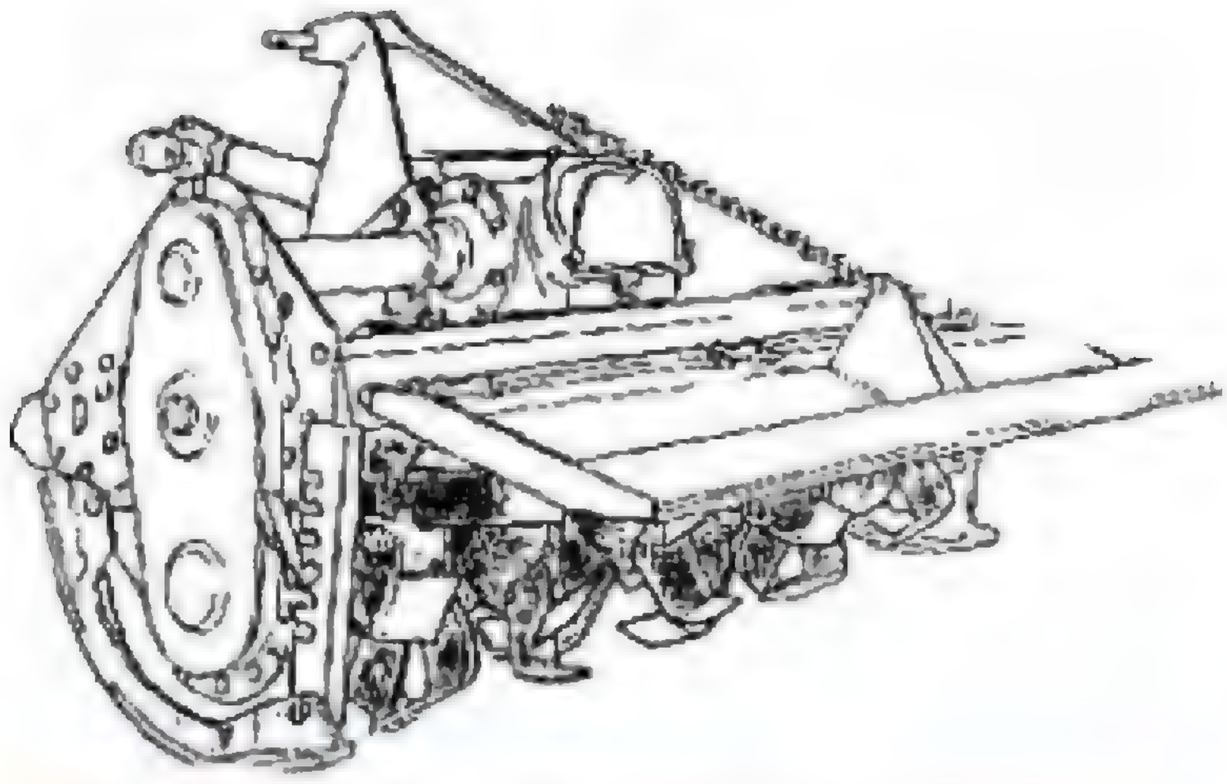
Many types of subsoilers are available. Most are chisel-like tools having curved or straight shanks, similar to chisel plows, though larger. Horsepower requirements are 20 HP minimum for each shank. Subsoiling depth should be 50% deeper than the compacted layer with shank spacing equal to the tillage depth for optimal results. However, tillage at this depth has a high power requirement which quadruples as tillage depth is doubled. An alternative is to subsoil one to two inches below the compaction layer with shanks spaced equal to the row spacing.

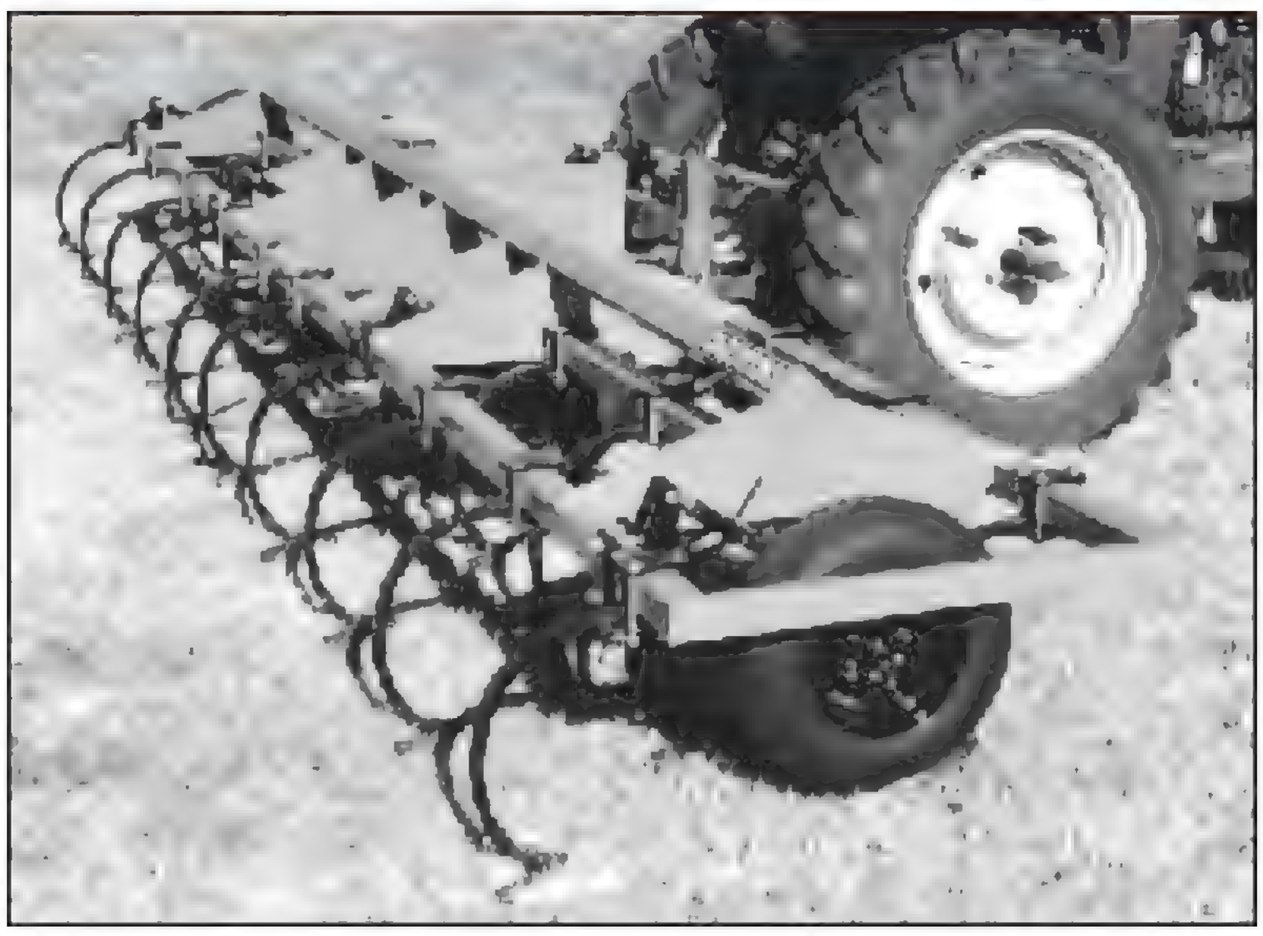
A subsoiler can be used along with any other tillage method. It is used at row spacings in row crop fields. For bed systems, a single shank or two shanks are used, depending on the bed width and soil type.

Rototillers are sometimes used for tillage. The problem with these is that it is difficult to till any soil with these due to their tendency to pulverize the soil. Attention should be paid to ground speed versus tine rotation speed to lessen this effect. Also, rototilling mixes soil layers more than other methods. A more appropriate use of rototillers is for cultivation.

Double Digging is a method of deep tillage done by hand labor. A spade and fork are used for deep tillage of beds up to 24 inches deep. A trench is dug with a spade the width of the bed, removing the top 12 inches and the soil is reserved. The subsoil is then loosened with a fork to another 12 inch depth. Next, a section of soil is moved forward into the trench and broken up, taking care not to mix or invert the soil layers. The resulting trench is loosened with the fork and this is repeated for the length of the bed. The reserved soil from the first trench is used to fill the last trench at the end of the bed. See John Jeavons, *How to Grow More Vegetables...*, for a complete description of this technique.

There are a number of advantages to this type of hand tillage. It loosens the soil to a depth of 24 inches, allowing for more water infiltration and storage and greater depth of root growth. Another advantage is that opening trenches allows for direct observation of soil quality while the main disadvantage is the amount of hand labor required. This limits the scale of a farming operation, especially where repeated tillage is necessary.





CULTIVATION

Cultivation differs from tillage in both its purpose and depth. The first purpose of cultivation is to manage the soil surface for optimal gas exchange and water absorption. This is done by breaking up any crusting of the soil caused by rainfall or irrigation. Decrusting of the soil surface should be done just deep enough to break the crust apart. Pulverizing the crust isn't necessary.

The second purpose of cultivation is to control weeds. This is done because weeds can usually out-compete crops for water and nutrients. Cultivation for weed control should be done at the minimal depth necessary to disturb the weed roots in order to kill them. This will avoid disturbing the crops' roots, destroying the soil structure, and bringing new weed seeds to the surface to sprout.

The same implements can be used for both these purposes. There are a large number of implements available for use with tractors, so the choice of which ones to use will depend on the crop, the farming methods (row or beds), and soil type. In a situation where a number of different kinds of crops are grown, a "tool bar" can be used. This is a piece of equipment that has a number of square bars on which cultivation implements can be mounted. It allows for fast and easy change of row spacing and numbers of implements. Good sources of information for what will work best in your situation are Extension agents and other farmers growing the same crops.

The third purpose of cultivation is the killing and incorporation of cover crops. This can be done with any tillage equipment that will kill the cover crop and incorporate most of the plant material. One of the best implements for this is the rototiller. A rototiller can cut the growing crown of plants from the roots, killing them. The action also breaks the outer covering of the plant material and incorporates it into the soil. This sets up conditions for rapid break down by the soil life. Spading machines with square spades also work well, if set at a shallow depth.

SUMMARY

The purpose of tillage is to improve soil structure by adding air to the soil without mixing the topsoil and subsoil. Organic matter will decrease when the layers are mixed and more oxygen is introduced into the soil. Clay soils should be tilled when the soil moisture is relatively low, but sandy or silty soils are best tilled when the soil moisture is relatively high. Chisel plows are an inexpensive, mechanically simple implement for tillage. Spaders incorporate cover crops exceptionally well but are expensive and tend to mix soil layers. Subsoilers will break up a tillage pan and allow water

and roots to penetrate deeper into the soil. Horsepower requirements for subsoilers are high. Rototillers are best for cultivation as they mix the soil layers. Double digging is an effective tillage technique, but the hand labor required makes it impractical on a large scale. Cultivation differs from tillage in the depth of soil disturbed. Cultivation is used to break up crust, control weeds and kill and incorporate cover crops.

UNIT SUMMARY

Soil is managed to support the numbers and diversity of soil life. Factors which should be managed are air, water, organic matter and minerals. The proper management of these factors provides the soil life with what it needs: oxygen, water, and food. These factors are all interrelated and necessary for optimal crop quality and quantity, so they all should be integrated into a total soil management plan.

Over-tillage of soil is destructive to both the soil structure and the soil life and should be avoided. Once a stable structure has been built throughout the tillage zone, no more tillage should be done until necessary. Surface cultivation, as shallow as possible to accomplish the task, should be used for management of the soil surface.

LESSON PLANS WITH OBJECTIVES - ORGANIC SOIL MANAGEMENT

I and II. INTRODUCTION AND SOIL AIR MANAGEMENT

OBJECTIVES:

1. Name the soil management factor that will result in the greatest positive plant response.
2. Give two reasons that it is important to have air in the soil.
3. Name the two gases that are of utmost importance in soil management.
4. Describe how each of the following factors affect gas exchange in the soil:
   temperature, rainfall or irrigation, gas diffusion, barometric pressure.
5. Name the procedures used to manage soil air.

LESSON PLAN:

1. Show the video of Crystal Organic Farm to start the class and discuss the focus questions.
2. Use the power point presentation slides 1-10 to focus on the importance of soil management and to present the factors involved in soil air management.
3. Incorporate in class demonstration of gas diffusion, use a strong smelling substance placed in a corner of the room. See how long it takes to reach the other side.
4. Student lab activities
    a. **Soil Temperature Variations**
    b. **Crust Formation**

III. SOIL WATER MANAGEMENT

OBJECTIVES:

4. Explain how the physical structure of water is responsible for the properties of surface tension, capillary action and the ability to dissolve most substances.
5. Describe where water is found in the soil and how it moves.
3. Name the procedures used to manage soil water.

LESSON PLAN:

1. Use slides 11-14 to discuss the factors involved in soil water management.
2. In class demonstrations include
    a. Models of the water molecule made of balls glued together
    b. Floating a needle on a glass of water demonstrates surface tension
    c. Overfilling a glass illustrates surface tension
    d. Place a straw and a strip of paper towel in a glass of water. The water goes up the paper towel but not the straw because of pore size of capillary action.
    e. Estimating moisture by feel and appearance can be a demonstration or student activity.
3. Student lab activities:
    a. **Percolation Lab**

IV. SOIL ORGANIC MATTER MANAGEMENT

OBJECTIVES:

1. Describe the importance of having organic matter in the soil.
2. Name the two classes of organisms responsible for production of most plant nutrients.
3. Describe three natural factors which tend to decrease and three which tend to increase soil organic matter.
4. State the affects of tillage and cover crops on soil organic matter.
5. Describe benefits and hazards of spreading raw manure or compost.

LESSON PLAN:

1. Use the power point slides 15-20 to discuss the factors involved in soil organic matter management.
2. Student lab activities:
    a. **Rate of Decomposition** – needs to be set up for a month to two weeks in warm weather
    b. **Soil Organic Matter** – long term project
    c. **Collecting Soil Organisms** – traps should be set up 3 days to a week prior to the lab.

IV. SOIL MINERAL MANAGEMENT

OBJECTIVES:

1. State two reasons mineral management is especially important in the southeast US.
2. List the three categories of soil minerals.
3. Name the primary procedure for managing soil minerals.
4. Take a soil sample.

LESSON PLAN:

1. Use the power point presentation slides 21-23 to present the reason why soil mineral management is so essential for the SE USA.
2. The power point presentation **Essential plant nutrients** presents the important minerals for plant production with pictures of the minerals.

3. Describe the soil test as the main way one can know the nutrient content of their soil. Use the power point presentation **Soil Test** to explain how to take a soil test. A sample of a soil test report can be found at **Soil test report.**
4. The lab **Soil test** can be done on the demonstration plot or other areas. Take the soil to the extension service or send off to a soil test lab for testing.
5. When the results come back, have students use the **Tables-Fertility of organic amendments** and **Recommendations for organic amendments in the article "How to Convert an Inorganic Fertilizer Recommendation to an Organic One"** to determine what amendments need to be added to the bed.

VI. TILLAGE & CULTIVATION

OBJECTIVES:

1. State the primary purpose of tillage.
2. Describe why soil layers should not be mixed.
3. List optimum conditions for tillage of clay soils and optimum conditions for sandy soils.
4. List three types of tillage equipment and an advantage and disadvantage of each.
5. State three reasons to cultivate.

LESSON PLAN:

1. Use the power point presentation slides 24-26 to emphasize that tillage is primarily done to incorporate air in the soil.
2. Use the USDA Publication **Estimating Soil Moisture by Feel and Appearance** to help students determine the proper way to time tilling.
3. Either use the **illustrations of tillage equipment** or if the equipment is available, show the students examples of the tillage equipment. Explain how each piece of equipment works and its purpose. Students could sketch the equipment and state its purpose.
4. If the time is appropriate, students could do the lab **Double-Digging** the demonstration plot and add the organic amendments. To demonstrate the technique use the power point presentation **Double digging.**

Teacher demonstrations

1. Demonstrate **gas diffusion** by opening a small bottle of some strong smelling liquid in front of room. See how long till students can smell.

2. Show the shape of a water molecule using 3 balloons tied together, a mickey mouse shape, a ball with two other balls on each side, but not exactly opposite of each other. Discuss how this shape results in a dipolar molecule, with slightly positive charges at the ends of the 2 ballons, mickey mouse ears, or balls on the sides, and slightly negative charges on the central atom. Use two of these models to show how water molecules stick together, attracted by opposite charges.

3. Demonstrate **cohesion** of water by floating needle on water.

4. Demonstrate **capillary action** by putting straw and paper towel in glass of water. Water will move up the paper towel but not straw because of pore size. (II)

5. Demonstrate visual examination of soil for **moisture content**. (VI)

6. Teacher demonstrates other **tillage equipment**, if available. (VI)

Focus Questions for Video – Crystal Organic Farm

1. How did the farmer get the land?
2. How long has he been farming?
3. What does he say is the "idea" behind organic farming?
4. How can you "grow" your soil?
5. Does he feel he is successful?
6. What values does he want to leave to his children?

COLLECTING SOIL ORGANISMS

Purpose – provide method to collect soil organisms.
The organisms will be collected outside and brought inside to observe under a magnifying glass or a dissecting microscope. Equipment needed for each team's collection is a quart-sized container like a cottage cheese container, a two-liter bottle, a piece of screen and some ethyl alcohol or antifreeze. Magnifying glasses or dissecting scopes are useful for identification. An ID sheet for soil organisms would be helpful . Two ways to collect soil organisms are presented.

Procedure A – one week

5. Make a pitfall trap by burying the cottage cheese container up to its lip in the soil.
6. Put about a half-inch of non-toxic antifreeze or ethyl alcohol in the bottom to preserve the specimens.
7. A roof to protect from rain may be arranged with twigs and leaves.
8. In a week collect the specimens that fell into the trap and examine.

Procedure B – 3 days

8. Make a Burlese funnel by cutting the bottom off a two-liter bottle about 1/3 from the bottom.
9. Put half-inch of alcohol or antifreeze in the bottom part of the bottle.
10. Turn the top part of the bottle upside down and place in the bottom part to act as a funnel.
11. Place a piece of ¼ inch rigid wire screen in the funnel.
12. Fill the funnel about half full of soil and place a light bulb over the funnel to drive the organisms down into the alcohol or antifreeze.
13. Leave for about 3 days.
14. Pour the antifreeze and the organisms into a dish to examine.

Various experiment could be set up with this procedure such as comparing the organisms of different types of ecosystems(lawn, woods, gardens) or soil from fields managed with chemical fertilizers and pesticides versus those managed organically.

SOIL TEMPERATURE VARIATIONS

Purpose – demonstrate the effect of moisture and color on soil temperature.

This experiment can be done outside, inside, or in a greenhouse. Materials needed are pots of light and dark soil and a soil thermometer.

1. Secure four equivalent large pots.
2. Two are filled with light colored soil and two with dark colored soil.
3. One of the light soil pots and one of the dark soil pots should be well watered while the other two are left dry. All pots should be labeled with their treatment (LW for light wet, DW for dark wet, LD for light dry and DD for dark dry).
4. The temperature of each pot should be measured and recorded. Leave the thermometer in the soil for at least 5 minutes to get a good reading. Record.
5. If inside, place in direct sunlight or under a lamp. Be sure all are equally exposed to the lamp. If outside, make sure the pots are in a sunny location.
6. Leave for 24 hours then measure the temperature of the soil in each pot again and record. Subtract the initial from the final temperature to get the difference.
7. Compare the LW to the DW and the LD to the DD to determine the effect of soil color. Compare the LW to the LD and the DW to the DD to determine the effect of water.

	Initial Temperature	Final Temperature	Difference in temp.
Dark Wet DW			
Dark Dry DD			
Light Wet LW			
Light Dry LD			

Questions:

1. Did the color of the soil have an effect on the soil temperature? If so, what was the effect?
2. Did the moisture level have an effect on the soil temperature? If so, what was the effect?

3. What is the relevance of soil temperature variations based on color of soil for farming?
4. Describe a farm situation where you could use the soil temperature variations due to moisture to benefit a crop.

CRUST FORMATION

Purpose – demonstrate the difference in crust formation.
This experiment can be done in a field, garden, small area beside a sidewalk or even in a couple of large pots.

1. Select 2 equivalent areas, A and B, and prepare the soil. Pulverizing the soil in the two areas will result in the most difference in crust formation.
2. Area A is left bare to be exposed to rain or simulated rain.
3. Cover Area B with mulch (straw, grass clippings, leaves, etc.) to a depth of 4-6 inches.
4. Expose both areas to the same rain or simulated rain.
5. Both areas should be left alone for a week or so.
6. Remove the layer of mulch.
7. Compare the amount of crusting on the top of the soil by trying to poke your finger through the top layer of soil. This can be a visual examination or the crust can actually be measured.

	Area A – no mulch	Area B - mulch
Amount of crust		

Questions:

1. Which area had the thickest layer of crust?
2. What effect would a layer of crust have on germinating seed?
3. What factor necessary for life is limited by a layer of crust?
4. What are some of the disadvantages of placing mulch on a seed bed?

PERCOLATION

Purpose – demonstrate the differing abilities of water to percolate through different types of soil.
This experiment is best done outside. Equipment needed is a shovel, bulb auger, or post-hole digger, a stop watch and a container to measure water.

1. Select locations with different soil types.
2. Assign a team to each site.
3. Each team should dig equivalent holes 6 inches deep.
4. Have each team pour 2 quarts of water into their hole and time how long it takes to completely drain. Clay soils may be very slow to drain and may have to be visited in hourly intervals to determine time.
5. This should be repeated 3 times
6. Take the average for the 3 repetitions. Each team should share results of their trials.
7. Compare the average time for each soil type.

Time to drain	Soil Type A	Soil Type B	Soil Type C	Soil Type D
Trial 1				
Trial 2				
Trial 3				
Average				

Questions:

1. Which soil type was the drained the quickest?
2. Which soil type was the slowest to drain?
3. What about the structure of the different soil types causes the difference in the rate at which the water to moves through the soil?
4. Why would a farmer be concerned about how fast water moves through the soil?

RATE OF DECOMPOSITION

Purpose – demonstrate the effect of different conditions on the ability of soil organisms to decompose organic matter.

This experiment should be done outside and **set up two weeks prior** to the activity. The teacher or students can set up the activity.

Materials needed:
mesh onion bags, coffee filters, and flags to mark burial sites.

1. Prepare the bags by cutting the mesh bags into 7 inch squares and folding each square in half and stapling the sides.
2. Place a 3 inch square of coffee filter in each bag and staple shut.
   Bury at least 3 bags in each type of ecosystem (garden bed, field, vacant lot, lawn, woods, etc.)
3. Bury the bags vertically, just until they are covered and flag the spot.

Two weeks later

1. Retrieve the bags,. Note the location and local conditions of each bag, such as type of vegetation, moisture, etc. The mesh bags should make retrieval easier.
2. Remove the filter paper from the bags, handling gently since the paper may be fragile. Visually estimate the percentage of the paper that remains and record in the data sheet. Take an average of the 3 papers and record.

Ecosystem	**% decomposition**			
	#1	#2	#3	
Garden bed				
Woods				
Lawn				
Field				
Vacant lot				

Note the environmental conditions of each ecosystem on the back of this sheet.

SOIL ORGANIC MATTER

Purpose – demonstrate the effect of cover crops on improving soil organic matter.

This experiment should be done outside. Materials needed are cover crop seed, shovels, tiller, or large equipment for preparing soil, if using a large area.

Fall

1. Measure off equivalent plots.
2. Prepare the soil for planting.
3. Follow the steps in "Taking a soil test" and have the two plots tested for soil organic matter.
4. Sow cover crop seed (rye, wheat, oats, etc.) on one plot and leave the other plot bare.

Spring

1. Turn under each plot, wait two weeks
2. Take samples for another soil test of organic matter from each plot.
3. Compare the results. Subtract the Fall OM from the Spring OM.

	Fall – organic matter	Spring – organic matter	Difference in organic matter
Plot A – cover crop			
Plot B – bare ground			

Questions:

1. Did both plots start with the same amount of organic matter? Why would that matter?
2. What was the difference in organic matter between fall and spring for each plot?
3. Did one show more of an increase or decrease than the other?
4. How do you explain your results?
5. How could a farmer use these results to increase the organic matter in their fields?
6. Why would a farmer want to increase the organic matter?

SOIL TESTS

Purpose – to collect valid samples of soil for testing

Equipment needed:

Clean plastic or stainless steel pail
Shovel/trowel

Procedure:

1. Determine plot to be tested.
2. Take samples of soil about 6-8 inches deep, being sure to get representative samples from all layers.
3. Take samples in a regular pattern from the entire plot and place all together in the pail. Avoid low areas or other areas with a concentration of minerals or organic matter.
4. Mix samples well and take out a one cup sample to be sent to the lab.
5. The samples can be taken to the extension office who will send them to the Soil, Plant and Water laboratory in Athens, GA. Results will be mailed back in about two weeks.

DOUBLE DIGGING

Purpose – to prepare the demonstration plot by personally participating in the double digging process.

1. Mark off the area of the demonstration plot with string (3.5' x 30').
2. If the bed is dry, water it well and let it set for a couple of days.
3. Remove all grass and weeds, including roots.
4. Dig across the 3.5 foot side, making a trough 12" by 12" .
5. Put each shovel full in a wheelbarrow.
6. Use a spading fork to loosen the soil in the bottom of the trench. Push the fork in as far as it will go and move it back and forth to loosen the soil.
7. Dig out a second trench, placing the soil in the previous trench. Try to keep the soil layers intact, not mixing.
8. Loosen the soil in the bottom of the second trench with the spading fork.
9. Continue digging trenches and filling the previous trench until the whole bed is dug.
10. Place the soil from the first trench in the last trench dug.

How to Convert an Inorganic Fertilizer Recommendation to an Organic One

Wayne McLaurin, Professor of Horticulture and Walter Reeves, Horticulture Educator/Media Coordinator

The success of any garden begins with the soil. A fertile, biologically active soil provides plants with enough nutrients for good growth. Fertilizers supplement or renew these nutrients, but they should be added only when a soil test indicates the levels of available nutrients in the soil are inadequate.

In the garden, whether you are growing annuals or perennials, vegetables or flowers, most of the crops have a few short months to grow and develop flowers and fruits. The soil must provide a steady, uninterrupted supply of readily available nutrients for maximum plant growth. Fertilizer form, particle size, solubility, and potential uptake are extremely important in fertility programs for gardening.

Organic gardeners place great emphasis on using natural minerals and organic fertilizers rather than manufactured ones in order to build their soil. If you use organic materials as all or part of your fertilization program, this bulletin will help you calculate the proper amount to use from the guidelines recommended by a soil test. Most organic materials must be used in combination since many do not have a balance of N-P-K; you should become familiar with the attached list of fertility values of organic sources of nutrients (Table 1).

Organic Matter

Organic matter is the varied array of carbon-containing compounds in the soil. Organic matter is created by plants, microbes and other organisms that live in the soil. Organic matter provides energy for biological activity. Many of the nutrients used by plants are held in organic matter until the organisms decompose the materials and release them for the plants' use. Organic matter also attracts and holds plant nutrients in an available state, reducing the amount of nutrients lost through leaching. It improves soil structure, so that air reaches plant roots and the soil retains moisture. The organic matter and the organisms that feed on it are central to the nutrient cycle.

Fertilizer Labels - What They Mean

Georgia law requires fertilizer producers to display the guaranteed analysis (grade) on the fertilizer container. A fertilizer grade or analysis that appears on the bag is the

percentages of nitrogen (N), phosphorus (P_20_5) and potassium (K_20) in the material. A 5-10-15 grade fertilizer contains 5 percent N, 10 per-cent P_20_5 and 15 percent K_20. A 50-pound bag of 5-10-15 fertilizer contains 2.5 pounds of N (50 x 0.05 = 2.5), 5 pounds of P_20_5 (50 x 0.10 = 5), and 7.5 pounds of K_20 (50 x 0.15 = 7.5), for a total of 15 pounds of nutrients. The other 35 pounds of material in the bag is filler or carrier.

The fertilizer ratio is the ratio of the percentages of N, P_20_5 and K_20 in the fertilizer mixture. Examples of a 1-1-1 ratio fertilizer are 10-10-10 and 8-8-8. These fertilizers have equal amounts of nitrogen, phosphorus, and potassium. An example of a fertilizer with a 1-2-3 ratio is 5-10-15. This fertilizer would have twice as much phosphorus and three times as much potassium as nitrogen.

Fertilizer Recommendations

It is difficult to recommend a specific fertilizer type or amount of fertilizer for any given situation. All fertilizer recommendations should take into consideration soil pH, residual nutrients, and inherent soil fertility. Fertilizer recommendations based on soil analyses are the very best chance for getting the right amount of fertilizer without over- or under-fertilizing.

Fertilizer recommendations based on soil tests result in the most efficient use of lime and fertilizer materials. This efficiency can occur only when valid soil sampling procedures are used to collect the samples submitted for analyses. To be beneficial, a soil sample must reliably represent the field, lawn, garden or "management unit" from which it is taken. If you have questions about soil sampling, please contact your local county extension office for information.

Soil pH

An underlying cause of poor fertility in Georgia is acidic soil. Raising the pH near 6.5 stimulates the activity of microorganisms that helps decompose organic matter and unlocks nutrients bonded to the soil particles.

Soil pH ranges are essential considerations for any fertilizer management program. The soil pH strongly influences plant growth, the availability of nutrients, and the activities of microorganisms in the soil. It is important to keep soil pH in the proper range for production of the best yields and high quality growth.

The best pH range for most plant growth in the garden is 6.0 to 6.5. Soils deficit in calcium or other alkaline substances are or can become too acidic. For example, Coastal Plain soils become strongly acid (pH 5 or less) with time if lime, a primary source of needed calcium, is not applied. A soil test, essential for deter-mining how much lime should be applied, should be done every two years.

Calcium will not spread quickly throughout the soil profile. It must be thoroughly incorporated before planting; therefore, lime should be broadcast and thoroughly incorporated to a depth of 6 to 8 inches to neutralize the soil acidity in the root zone. To allow adequate time for neutralization of soil acidity (raising the pH), lime should be applied and thoroughly incorporated two to three months before seeding or transplanting. However, if application can not be made this early, liming will still be very beneficial if applied and incorporated at least one month prior to seeding or transplanting.

The preferred liming material for Georgia gardeners is dolomitic limestone. In addition to calcium, dolomitic limestone also contains 6 to 12 percent magnesium in which all Georgia soils routinely become deficient.

Environmental Effects on Organic Nutrient Uptake

1. **Temperature/Soil Temperature -** Early spring in Georgia is cool and soil temperatures rise slowly to the point where microorganisms are active. Until the soil warms sufficiently and the fertilizer materials are broken down into their useable form, organic fertilizers may not successfully stimulate plant growth. This may cause stunting of growth early in the season when using organic fertilizers.
2. **pH -** Too low or too high a pH in the soil profile can cause the nutrients to become unavailable. Most plants grow well at a pH of 6.0 - 7.0. The exceptions are Irish potatoes which are grown at a pH of approximately 5.5. Potatoes are grown at this pH to reduce the incidence of scab disease (*Streptomyces* spp.). Also, blueberries grow at a pH of less than 5.0, while the rhododendron family grows well around 5.5.

To replace the inorganic fertilizer recommendations from the Soil Test Report with organic fertilizer:

Organic Fertilizer for 1000 Square Feet of Garden Space

1. Calculate the nitrogen (N) recommendation first.

Example:

Soil test results recommend 20 lbs. of 5-10-15 plus 1.0 lb of ammonium nitrate (34-0-0) per 1,000 sq. ft. of garden. Use blood meal (12-1.5-0.6) for your nitrogen source of fertilizer. Divide the nitrogen number of the inorganic source (5) by the nitrogen number of the blood meal (12). Multiply this answer times the lbs. of inorganic fertilizer recommended.

5 ÷ 12 = .41 x 20 lbs. = 8.2 lbs. of blood meal per 1,000 sq. ft.

For the 1.0 lb. of ammonium nitrate (34-0-0) called for using blood meal calculate:

34 ÷ 12 = 2.8 x 1.0 lb. = 2.8 lbs. of blood meal extra

Total organic nitrogen = 11 lbs. of blood meal (8.2 lbs. + 2.8 lbs.)(The 1.5 phosphorus and 0.6 potassium is not significant enough to be counted.)

2. Calculate the phosphorus ($P_2 0_5$) recommendation next.

Example:

Use steamed-bone meal (approx. 1-11-0) for the phosphorus source. Divide the phosphorus number (10) by the organic phosphorus number (11) and you get 0.91. Multiply 0.91 times the 20 lbs. needed for a total of 18.2 lbs. of steamed-bone meal required for 1000 sq. ft.

Total organic phosphorus = 10 ÷ 11 =0.91 x 20 lbs. = 18.2 lbs. of steamed-bone meal per 1,000 sq. ft.

3. Calculate the potassium ($K_2 0$) recommendation next.

Example:

Sulfate of Potash Magnesia or Sul-Po-Mag (0-0-22) is recommended for the potassium requirements. Dividing the potassium number recommended (15) by the potassium number of the Sul-Po-Mag (22) equals 0.682. Multiplying 0.682 times 20 lbs. of fertilizer needed results in 13.6 lbs of Sul-Po-Mag per 1,000 sq. ft.

Total organic potassium = 15 ÷ 22 = 0.682 x 20 lbs. = 13.6 lbs. of Sul Po Mag per 1,000 sq. ft.

Note - If you use wood ashes, it is recommended that no more than 10-12 lbs. be used per.1,000 sq. ft./year due to its high salt concentrations.

Assuming blood meal, bone meal, and Sul-Po-Mag are used, the equivalent to 20 lbs. of 5-10-15 plus 1.0 lb of ammonium nitrate per 1,000 sq. ft. of garden is 11 lbs. of blood meal, 18.2 lbs. of steamed bone meal, and 13.6 lbs. of Sul-Po-Mag.

Organic Fertilizer for 100 Feet of Row

To replace inorganic fertilizer recommendations with organic fertilizer per 100 linear feet of row

1. Calculate the nitrogen recommendation first.

Example:

Soil test results recommends 7 lbs. of 5-10-15 plus 0.5 lbs. of ammonium nitrate per 100 linear feet of garden row. Using blood meal (12-1.5-0.6) for your nitrogen source of fertilizer, divide the nitrogen number of the inorganic source (5) by the nitrogen number

of the blood meal (12). Multiply this answer times the lbs. of inorganic fertilizer recommended.

5 ÷ 12 = .41 x 7 lbs. = 2.9 lbs. of blood meal per 100 linear feet of row

For the 0.5 lbs. of ammonium nitrate called for using blood meal calculate:

34 ÷ 12 = 2.8 x 0.5 lbs. = 1.4 lbs. of blood meal extra
Total Organic Nitrogen = 4.3 lbs. of blood meal per 100 linear feet of row

2. Calculate the phosphorus recommendation next.

Example:

Use steamed-bone meal (approx. 1-11-0) for the phosphorus source. Divide the phosphorus number (10) by the organic phosphorus number (11) and you get 0.91. Multiply 0.91 times the 7 lbs. needed for a total of 6.4 lbs. of steamed-bone meal required per 100 linear foot of row.

Total organic phosphorus = 10 ÷ 11 = 0.91 x 7 lbs.= 6.4 lbs. of steamed-bone meal per 100 linear feet of row

3. Calculate the potassium recommendation next.

Example:

Use Sul-Po-Mag (0-0-22) for the potassium requirements. Dividing the potassium number needed (15) by the potassium number of the Sul-Po-Mag (22) equals 0.682. Multiplying 0.682 times 7 lbs. of fertilizer needed results in 13.6 lbs of Sul-Po-Mag per 100 linear foot of row.

Total organic potassium = 15 ÷ 22 = 0.682 x 7 = 13.6 lbs. of Sul Po Mag per 100 linear feet of row

Assuming blood meal, bone meal, and Sul-Po-Mag are used, the equivalent to 7 lbs. of 5-10-15 plus 0.5 lb of ammonium nitrate per 100 linear feet of row of the garden is 4.3 lbs. of blood meal, 6.4 lbs. of steamed bone meal, and 13.6 lbs. of Sul-Po-Mag.

Table 1

Guide to the Mineral Nutrient Value of Organic Fertilizers

(Percent[1])

Materials	N	P_2O_5	K_2O	Relative Availability
Alfalfa Meal	3.0	1.0	2.0	Medium-Slow
Blood Meal	12.0	1.5	0.6	Medium-Rapid
Bone Meal (steamed)	0.7-4.0	11.0-34.0	0.0	Slow-Medium
Brewers Grain (wet)	0.9	0.5	0.1	Slow
Castor Pomace	5.0	1.8	1.0	Slow
Cocoa Shell Meal	2.5	1.0	2.5	Slow
Coffee Grounds (dry)	2.0	0.4	0.7	Slow
Colloidal Phosphate	0.0	18.0-24.0	0.0	Slow
Compost (not fortified)	1.5	1.0	1.5	Slow
Cotton Gin Trash	0.7	0.2	1.2	Slow
Cottonseed Meal (dry)	6.0	2.5	1.7	Slow-Medium
Eggshells	1.2	0.4	0.1	Slow
Feather	11.0-15.0	0.00.0		Slow
Fertrell - Blue Label	1.0	1.0	1.0	Slow
Fertrell - Gold Label	2.0	2.0	2.0	Slow
Fertrell - Super	3.0	2.0	3.0	Slow
Fertrell - Super "N"	4.0	3.0	4.0	Slow
Fish Meal	10.0	4.0	0.0	Slow
Fish Emulsion	5.0	2.0	2.0	Medium-Rapid
Fish Scrap (dry)	3.5-12.0	1.0-12.0	0.8-1.6	Slow
Garbage Tankage (dry)	2.7	3.0	1.0	Very Slow
Grape Pomace	3.0	0.0	0.0	Slow
Granite Dust	0.0	0.0	6.0	Very Slow
Greensand	0.0	1.0-2.0	5.0	Slow
Guano (bat)	5.7	8.6	2.0	Medium
Guano (Peru)	12.5	11.2	2.4	Medium
Hoof/Horn Meal	12.0	2.0	0.0	Medium-Slow
Kelp[2]	0.9	0.5	1.0-4.0	Slow
Manure[3] (fresh)				
Cattle	0.25	0.15	0.25	Medium
Horse	0.3	0.15	0.5	Medium
Sheep	0.6	0.33	0.75	Medium
Swine	0.3	0.3	0.3	Medium
Duck	1.1	1.4	0.5	
Poultry (75% water)	1.5	1.0	0.5	Medium-Rapid
Poultry (50% water)	2.0	2.0	1.0	Medium-Rapid
Poultry (30% water)	3.0	2.5	1.5	Medium-Rapid

Poultry (15% water)	6.0	4.0	3.0	Medium-Rapid
Manure[3] (dry)				
Cricket Manure	3.0	2.0	1.0	Medium Rapid
Goat	2.7	1.8	2.8	Medium
Dairy	0.7	0.3	0.6	Medium
Steer	2.0	0.5	1.9	Medium
Horse	0.7	0.3	0.5	Medium
Hog	1.0	0.7	0.8	Medium
Sheep	2.0	1.0	2.5	Medium
Rabbit	2.0	1.3	1.2	Medium
Marl	0.0	2.0	4.5	Very Slow
Mushroom Compost	0.7	0.9	0.6	
Sulfate of Potash Magnesia[4]	0.0	0.0	22.0	Rapid to Medium
Soybean Meal	6.7	1.6	2.3	Slow
Urea[5]	42.0-46.0	0.0	0.0	Rapid
Wood Ashes[6]	0.0	1.0-2.0	3.0-7.0	Rapid

Some of the materials may not be available because of restricted sources.

[1] The percentage of plant nutrients is highly variable; average percentages for materials are listed.
[2] Contains common salt, sodium carbonates, sodium and potassium sulfates.
[3] Plant nutrients, available during year of application, vary with amount of straw/bedding and method of storage.
[4] Also known as Sul-Po-Mag or K-Mag.
[5] Urea is an organic compound; but as manufactured sources are synthetic, it is doubtful that most organic gardeners would consider it acceptable.
[6] Potash content depends on the tree species burned. Wood ashes are alkaline, containing approximately 32% CaO.

For those who do not want to figure out the equivalent weights, here is an approximation of amounts of ingredients to use to attain the correct amounts of organic fertilizers called for in the soil test for 1,000 square feet.

Table 2
Organic Fertilizer Recommendations

Recommendations for Inorganic Fertilizers	Nitrogen [1] Needed for 5 lbs. of 5-10-15 From Organic Source	Phosphorus Needed for 5 lbs. of 5-10-15 From Organic Source	Potassium Needed for 5 lbs. of 5-10-15 From Organic Source
5 lbs. 5-10-15 (using component fertilizers)	2.0 lbs. blood meal 8.3 lbs. alfalfa meal 4.2 lbs. cotton seed meal 2.0 lbs. feather meal 2.5 lbs. fish meal 2.0 lbs. hoof meal 8.0 lbs. of cricket manure 4.0 lbs soybean meal	4.5 lbs. bone meal 1.4 lbs. colloidal phosphate	3.1 lbs. Sul-Po-Mag 15.0 lbs. greensand 15.0 lbs. granite dust 25.0 lbs. kelp
	Nitrogen Needed for 5 lbs. of 6-12-12	Phosphorus Needed for 5 lbs. of 6-12-12	Potassium Needed for 5 lbs. of 6-12-12
5 lbs 6-12-12 (using component fertilizers)	2.0 lbs. blood meal 10.0 lbs. alfalfa meal 5.0 lbs. cotton seed meal 2.0 lbs. feather meal 2.5 lbs. fish meal 2.5 lbs. hoof meal 10.0 lbs. of cricket manure 3.7 lbs soybean meal	5.5 lbs. bone meal 3.0 lbs. colloidal phosphate	2.7 lbs Sul-Po-Mag 12.0 lbs. greensand 12.0 lbs. granite dust 20.0 lbs. kelp
	Nitrogen, Phosphorus and Potassium Needed for 5 lbs. of 10-10-10		
5 lbs. 10-10-10 (for even analysis fertilizers)	33.3 lbs. of compost (1.5-1-1.5) 33.0 lbs. of 30% poultry manure (3-2.5-1.5) 50 lbs of Fertrell 1-1-1		
	Nitrogen Needed for 5 lbs. of 10-10-10	Phosphorus Needed for 5 lbs. of 10-10-10	Potassium Needed for 5 lbs. of 10-10-10
5 lbs. 10-10-10 (using component fertilizers)	4.2 lbs. blood meal 17.0 lbs. alfalfa meal 8.3 lbs. cotton seed meal 3.3 lbs. feather meal 5.0 lbs. fish meal 4.2 lbs. hoof meal 16.7 lbs. of cricket manure 7.5 lbs soybean meal	4.5 lbs. bone meal 2.8 lbs. colloidal phosphate	2.3 lbs. Sul-Po-Mag 10 lbs. greensand 16.6 lbs. of kelp

[1] Use only one of these amounts of fertilizer materials to equal 5 lbs. of nitrogen or use one-half of 2 different materials to make up the 5 lbs. of nitrogen required. The same process can be used for any other nutrient in the chart.

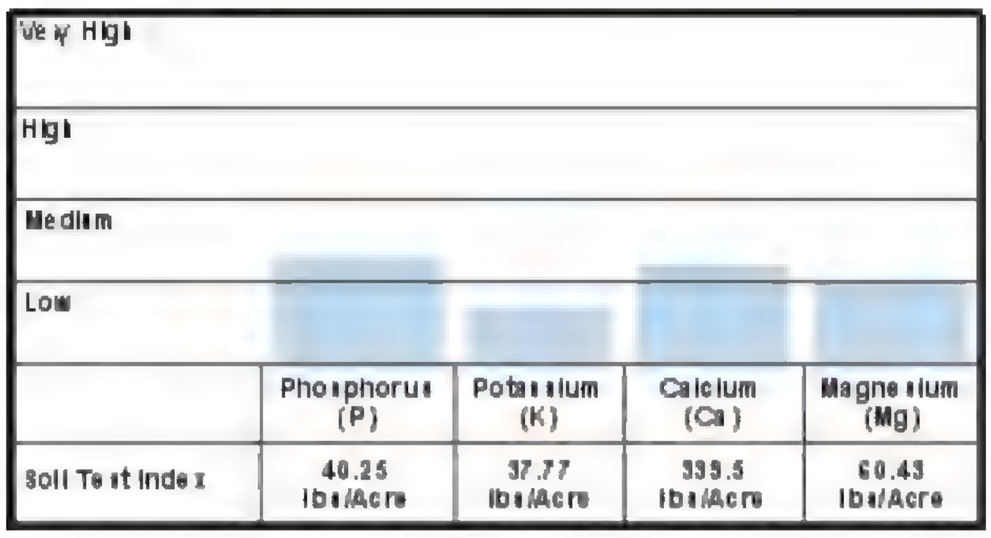
The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service

Soil Test Report

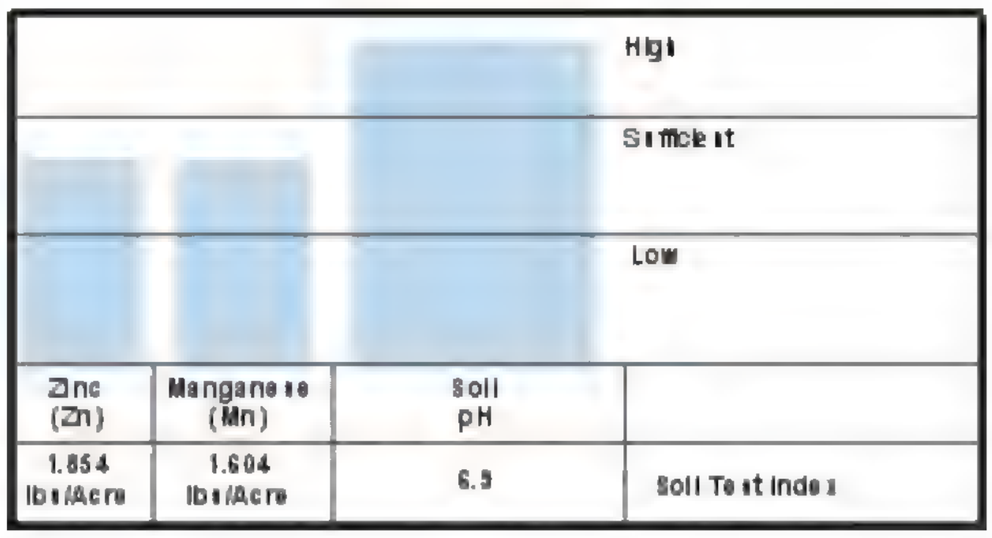
Sample ID **Soil, Plant and Water Laboratory** **(CEC/CEA Signature)**

Grower Information	***Lab Information***	***County Information***
Client: **John Doe**	Lab #1755	**Tift County**
123 Nowhere Lane	Completed: 05/10/2000	P O Box 7548
Sample: 1	Printed: 05/10/2000	Tifton, GA 31793
Crop: Vegetable Garden		

Results



	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Soil Test Index	40.25 lbs/Acre	37.77 lbs/Acre	339.5 lbs/Acre	60.43 lbs/Acre



Zinc (Zn)	Manganese (Mn)	Soil pH	
1.854 lbs/Acre	1.604 lbs/Acre	6.3	Soil Test Index

Recommendations

Limestone: 0 pounds per 1000 square feet

Broadcast 20 pounds of 5-10-15 plus 1 pound of ammonium nitrate per 1000 square feet, or apply 7 pounds of 5-10-15 plus ½ pound of ammonium nitrate per 100 linear feet of row.

The recommendation given above is for medium feeders, which include crops such as beans, beets, broccoli, cantaloupes, corn, cucumbers, eggplant, greens (kale, mustard, turnip, collards), okra, English peas, peppers, radish, squash, watermelon and sweet potatoes.

For heavy feeders such as cabbage, lettuce, onions, tomatoes and Irish potatoes, double the recommendation.

For light feeders such as southern peas, reduce the recommendation in half.

Apply 1 tablespoon of borax per 100 feet of row to broccoli and root crops such as turnips and beets. This can be applied by mixing the borax thoroughly with approximately 1 quart of soil in a container and then applying the mixture along the row; or it can be mixed with a quart of water and applied to the soil in solution.

For sweet corn, apply 1 tablespoon of zinc sulfate per 100 feet of row and sidedress with 1 to $1^{1}/_{3}$ pounds of

ammonium nitrate (or equivalent amount of nitrogen) per 100 feet of row.

PUTTING KNOWLEDGE TO WORK

The University of Georgia and Fort Valley State University, the U.S. Department of Agriculture and counties of the state cooperating.
The Cooperative Extension Service offers educational programs, assistance and materials to all people without regard to race, color, national origin, age, sex or disability. An equal opportunity/affirmative action organization committed to a diverse work force.

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Gale A. Buchanan, Dean and Director

Guidelines for Estimating Soil Moisture Conditions

Soil Moisture Deficit (SMD) in inches per foot when the feel and appearance of the soil are as described				
Available Soil Moisture Percent	**Coarse Texture**	**Moderately Coarse Texture**	**Medium Texture**	**Fine Texture**
Soil Texture	Fine Sand and Loamy Fine Sand	Sandy Loam and Fine Sandy Loam	Sandy Clay Loam, Loam, and Silt Loam	Clay, Clay Loam, or Silty Clay Loam
Available Soil Moisture Percent	Available Water Capacity 0.6 to 1.2 inches per foot	Available Water Capacity 1.3 to 1.7 inches per foot	Available Water Capacity 1.5 to 2.1 inches per foot	Available Water Capacity 1.6 to 2.4 inches per foot
0 to 25	Dry, loose, will hold together if not disturbed, loose sand grains on fingers with applied pressure. SMD 1.2 to 0.5	Dry, forms a very weak ball, aggregated soil grains break away easily from ball. SMD 1.7 -1.0	Dry. Soil aggregations break away easily. no moisture staining on fingers, clods crumble with applied pressure. SMD 2.1-1.1	Dry, soil aggregations easily separate, clods are hard to crumble with applied pressure SMD 2.4-1.2
25 to 50	Slightly moist, forms a very weak ball with well-defined finger marks, light coating of loose and aggregated sand grains remain on fingers. SMD O.9-0.3	Slightly moist, forms a weak ball with defined finger marks, darkened color, no water staining on fingers, grains break away. SMD 1.3-0.7	Slightly moist, forms a weak ball with rough surfaces, no water staining on fingers, few aggregated soil grains break away. SMD1.6-0.8	Slightly moist, forms a weak ball, very few soil aggregations break away, no water stains, clods flatten with applied pressure SMD 1.8-0.8

50 to 75	Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, moderate water staining on fingers, will not ribbon. SMD O.6-0.2	Moist, forms a ball with defined finger marks. very light soil/water staining on fingers. darkened color, will not slick. SMD O.9-0.3	Moist, forms a ball, very light water staining on fingers, darkened color, pliable, forms a weak ribbon between thumb and forefinger. SMD 1.1- 0.4	Moist. forms a smooth ball with defined finger marks, light soil/water staining on fingers, ribbons between thumb and forefinger. SMD l.2-0.4
75 to 100	Wet, forms a weak ball, loose and aggregated sand grains remain on fingers, darkened color, heavy water staining on fingers, will not ribbon. SMD O.3-0.0	Wet, forms a ball with wet outline left on hand, light to medium water staining on fingers, makes a weak ribbon between thumb and forefinger. SMD O.4-0.0	Wet, forms a ball with well defined finger marks, light to heavy soil/water coating on fingers, ribbons between , thumb and forefinger. SMD O.5 -0.0	Wet, forms a ball, uneven medium to heavy soil/water coating on fingers, ribbons easily between thumb and forefinger. SMD O.6-0.0
Field Capacity (100 percent)	Wet, forms a weak ball, moderate to heavy soil/water coating on fingers, wet outline of soft ball remains on hand. SMD 0.0	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking,medium to heavy soil/water coating on fingers. SMD 0.0	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, medium to heavy soil/water coating on fingers. SMD 0.0	Wet, forms a soft ball, free water appears on soil surface after squeezing or shaking, thick soil/water coating on fingers, slick and sticky. SMD 0.0

TOUCH AND FEEL METHOD

Purpose: Determine the moisture content of soil.

The feel and appearance of soil vary with texture and moisture content. Soil moisture conditions can be estimated, with experience, to an accuracy of about 5 percent. Soil moisture is typically sampled in one-foot increments to the root depth of the crop at three or more sites per field. It is best to vary the number of sample sites and depths according to crop, field size, soil texture, and soil stratification. For each sample the "feel and appearance method" involves:

1. Obtaining a soil sample at the selected depth using a probe, auger, or shovel;
2. Squeezing the soil sample firmly in your hand several times to form an irregularly shaped "ball";
3. Squeezing the soil sample out of your hand between thumb and forefinger to form a ribbon;
4. Observing soil texture, ability to ribbon, firmness and surface roughness of ball, water glistening, loose soil particles, soil/water staining on fingers, and soil color. [Note: A very weak ball will disintegrate with one bounce of the hand. A weak ball disintegrates with two to three bounces];
5. Comparing observations with photographs and/or charts to estimate percent water available and the inches depleted below field capacity.

UNIT 3 – PLANTS

I. INTRODUCTION

II. BASICS OF PLANT ANATOMY

1. Plant structures
2. Plant cell

III. BASICS OF PLANT PHYSIOLOGY

1. Transport in plants
2. Photosynthesis
3. Transport of glucose
4. Plant hormones
5. Plant nutrient uptake

IV. PLANT TAXONOMY

V. PLANT LIFE/ SOIL LIFE RELATIONSHIPS

1. Plant/soil relationships
2. Manipulation by plants

VI. UNIT SUMMARY

INTRODUCTION

While good soil management is essential to healthy plants, an understanding of the basic anatomy and physiology of plants is also important. Many management decisions are based on the knowledge of the way plants obtain water, carbon dioxide, oxygen, and mineral nutrients they need to live. Knowledge of the action of plant hormones and symbiotic relationships will inform crop management decisions. Better crops are achieved through enhancing the conditions that are conducive to plant growth and reproduction.

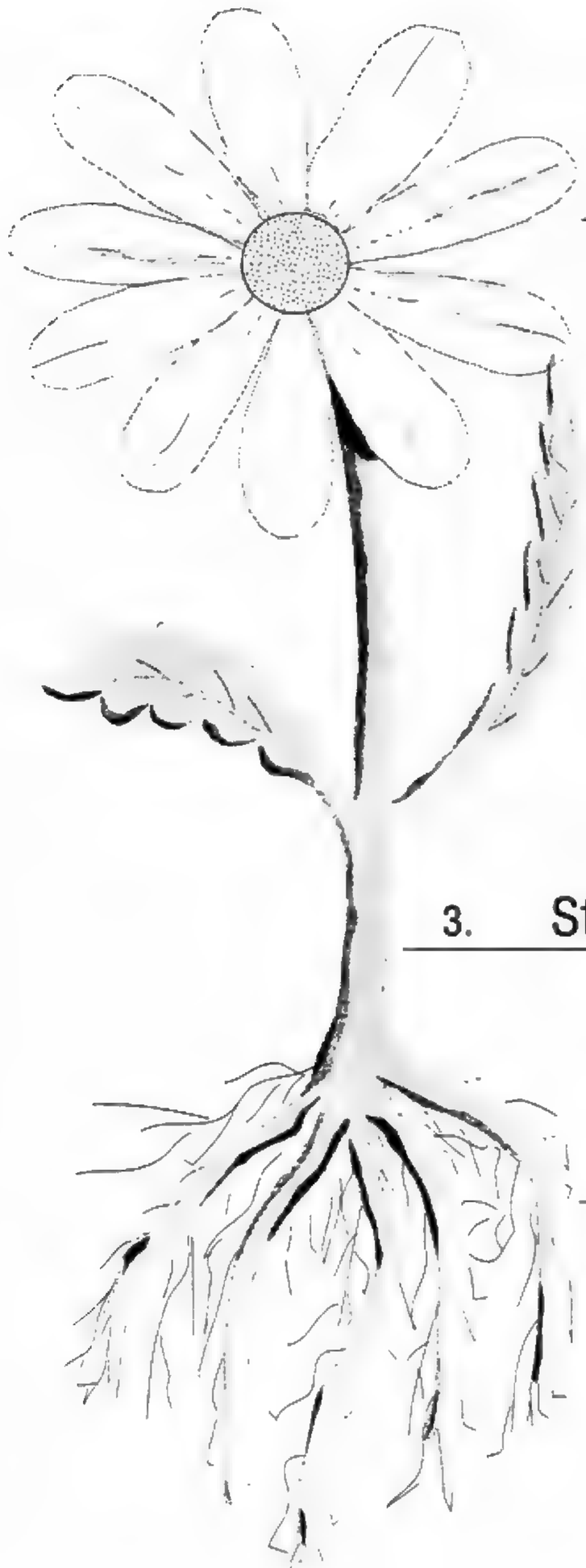
PLANT ANATOMY

Objectives

1. *Identify the basic structures of plants.*
2. *List the 3 tissue types of plants and the general functions of each.*
3. *Name the substances that flow through the xylem and those that flow through the phloem.*
4. *List 4 ways plant and animal cells differ.*

PLANT STRUCTURES

The basic plant structures in flowering plants that produce fruit and vegetables are roots, stems, leaves, flowers, fruits and seeds. The leaf, stem, and root are vegetative, or non-fruiting, structures concerned with the growth, nutrition, and development of a plant. In general, roots grow through the soil and absorb water and nutrients. The stems provide support for the plant and move nutrients from the roots to the other parts of the plant. The leaves produce food by converting light energy to sugar.



Roots, stems, and leaves are called organs because each is composed of one or more tissues. Tissues are groups of similar cells organized to carry out one or more specific functions. Plants have only three tissue types: dermal, ground and vascular. (Flowers, fruits, and seeds are concerned with reproduction and are composed of one or more different organs.)

From Oregon State University Extension

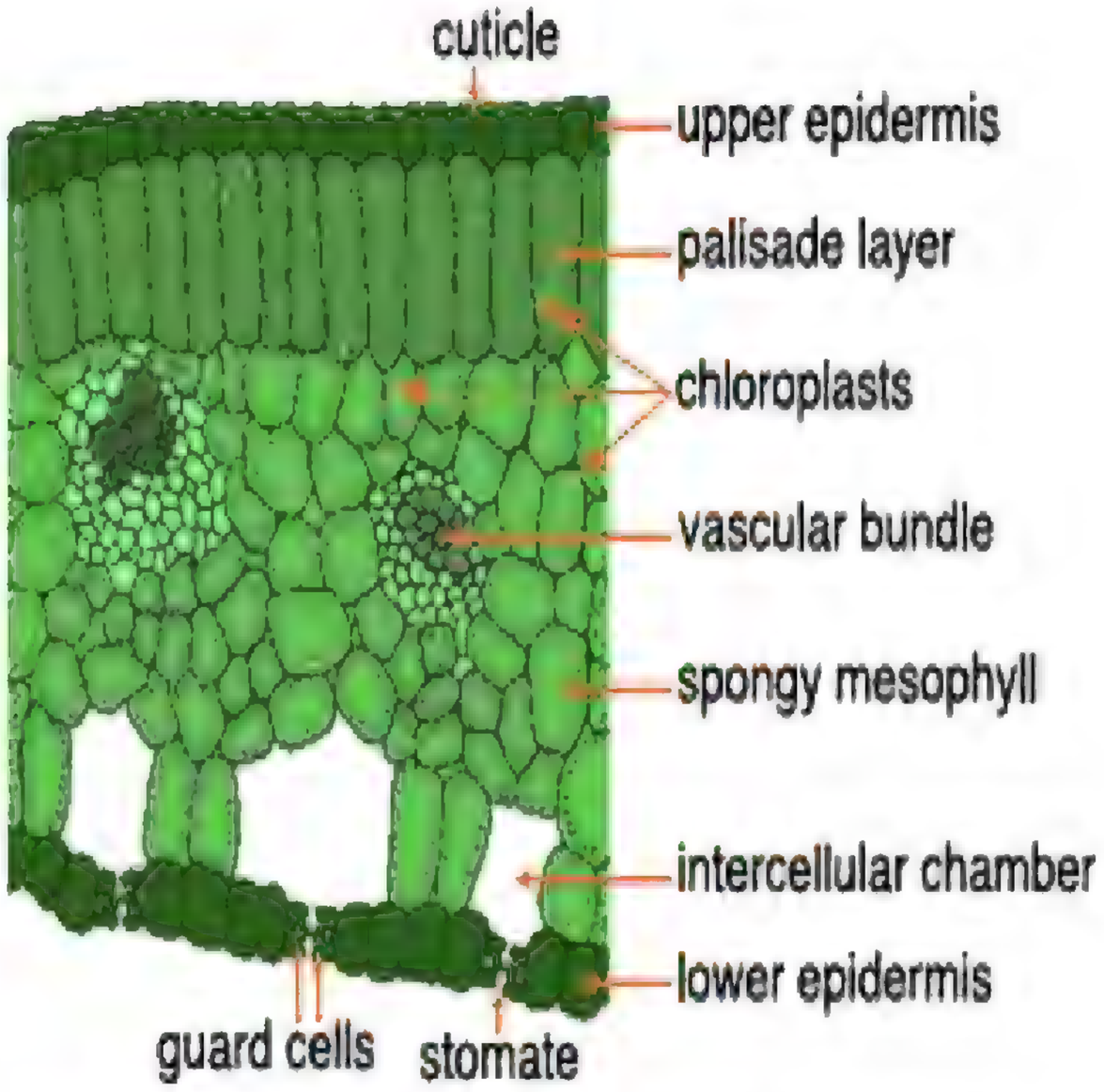


Figure 12. Leaf cross section

Dermal tissue covers the outer surface of herbaceous, or non-woody, plants. The outer layer of cells is called the epidermis. The epidermis consists of a single layer of living cells that are closely packed, which functions to protect the underlying tissues. Stomata, openings formed by guard cells, are found in the epidermis. The epidermal walls are thickened and covered with a thin waterproof layer called the cuticle. The cuticle prevents the desiccation of inner tissues and thus prevents water loss.

The stomata allow gaseous exchange for the processes of respiration and photosynthesis. These are pores, usually located on the underside of leaves, for the collection of carbon dioxide from the atmosphere. They also function as an opening through which water that has been vaporized inside the plant can be released. This acts as a cooling mechanism for the plant. The stomata have guard cells which open and close the pore.

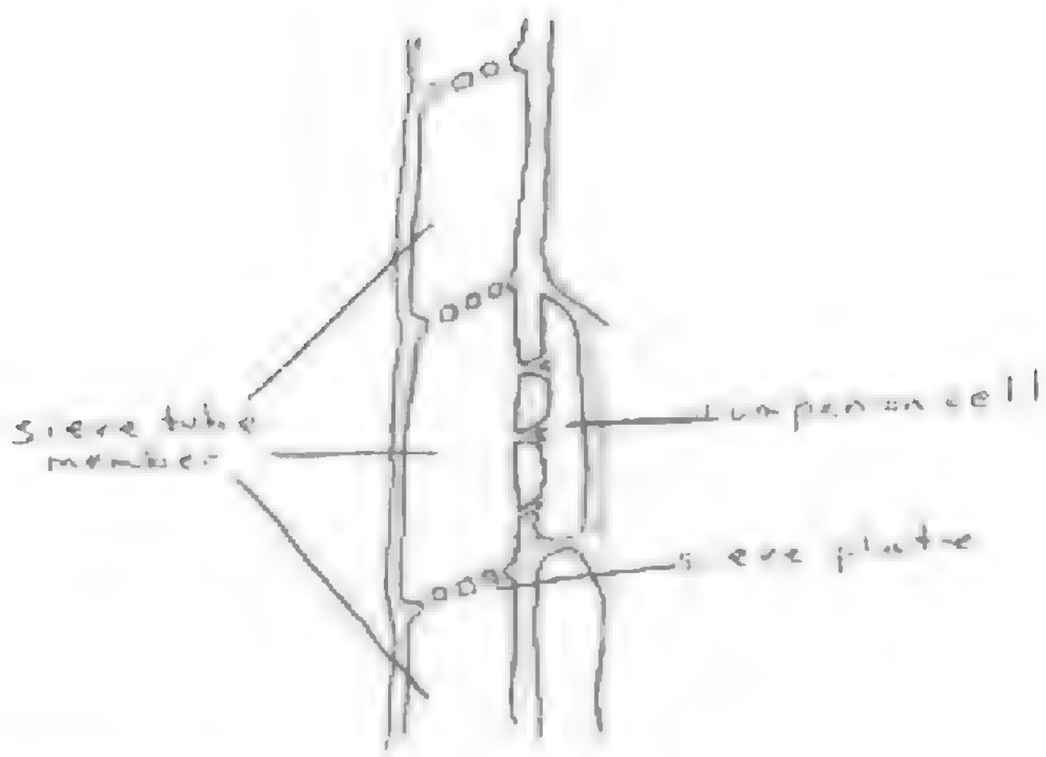
Ground tissue is composed of small, thick-walled cells on the inside of the epidermis. These layers of cells are followed by larger thin-walled cells with intercellular air spaces. The first layer of these small, thick-walled cells strengthens the stem. The second layer stores synthesized organic food produced by the plant such as starch. Intercellular air spaces allow the exchange of gases between cells.

The vascular bundles are found scattered throughout the ground tissue. These are tube-like structures through which the fluids move inside the plant. The vascular bundles occurring nearer the outside of the stem are smaller and are closer to one another. Vascular bundles are composed of two different types of tubes: xylem and phloem.

Xylem vessels are relatively large and found within an irregular intercellular air space. Water and dissolved ions from the root system are transported to all other parts of the plant through the xylem. The xylem is a one-way transport system from the roots to other parts of the plant. Xylem tissue is composed of dead cells joined together to form long empty tubes. The ends of these cell walls are either full of holes, or are absent completely, allowing for flow. Before dying, the cells form thick cell walls containing lignin. Lignin is a woody substance that makes the xylem vessels very strong so that they don't collapse under pressure. They also help to give stems strength.

Xylem

Phloem is composed of smaller, thin-walled cells. Synthesized organic food such as carbohydrate is transported from the leaves to all other parts of the plant through the phloem. Phloem is a two-way system that can transport food and nutrients to and from each structure. Phloem tissue is composed of sieve tube cells, which form long columns with holes in their end walls called sieve plates.



Phloem

These cells are alive, but they lose their nuclei and other organelles, and their cytoplasm is reduced to strands around the edge of the cells. These strands pass through the holes in the sieve plates, forming continuous filaments. The center of these tubes is empty. Each sieve tube cell is associated with one or more companion cells, normal cells with nuclei and organelles. These companion cells are connected to the sieve tube cells. They provide the phloem cells with proteins, adenosine triphosphate (ATP) and other nutrients. Additional information about ATP is provided in the section below on Photosynthesis.

PLANT CELLS

Plant cells differ from animal cells in some significant ways. Plant cells have a thick, impermeable cell wall and animals have only a thin, permeable membrane. Animal cells absorb and give off gases and nutrients directly through their cell membranes. Plant cells transfer gases and nutrients between adjacent cells through small perforations that connect each cell with all those adjacent to it.

Another difference is that plant cells contain chloroplasts and vacuoles. Chloroplasts are the structures within plant cells where light energy is used to make the hormone used in sugar production. These are usually contained in the leaf cells and give them their green color.

Vacuoles are empty spaces within the plant cells. They have their own membrane within the cell that is separate from the cell membrane. One of the functions of vacuoles is to store some of the sugar and carbohydrates the plant produces and uses for food.

SUMMARY

Roots, stems, leaves, flowers and fruits are the basic plant structures. Roots, stems, and leaves are made up of dermal, vascular, and ground tissue. Dermal tissue provides the outside covering of the structure. Vascular tissue makes up the structures that carry water and nutrients in the plant. Ground tissue make up the bulk of the plant. Xylem carries water and minerals from the roots, while phloem carries the sugars from the leaves

Plant and animal cells differ in that animal cells do not have a cell wall and so transfer of gases between cells is different. Plant cells contain chloroplasts and vacuoles, whereas animal cells do not.

PLANT PHYSIOLOGY

Objectives:

1. *Describe how water moves from roots to stems to leaves.*
2. *Identify 3 factors which will effect transpiration.*
3. *Define photosynthesis and state the location of the process.*
4. *State the formula, in words, for photosynthesis.*
5. *Name the plant structure which is the "source" of glucose and the structure which is the "sink".*
6. *Define endogenous rhythm.*
7. *Name 5 classes of plant hormones and the general effect they have on plants.*
8. *Describe how carbon dioxide, minerals, and water are each absorbed by plants.*

TRANSPORT OF WATER AND NUTRIENTS

Plants don't have a circulatory system like animals but they do have a complicated system for transporting water and nutrients. This transportation system starts in the roots. Roots absorb water and dissolved salts, ions and other nutrients. These enter the xylem in the root tissue, creating a slight upward pressure called root pressure.

Root pressure is from water moving through root cells by osmosis, the diffusion of water through cell membranes. This movement of water through root cell membranes is only enough force to move the water and nutrients a few centimeters up the stem, so another force is responsible for most of the transportation.

Since the xylem tubes are made up of dead cells, no osmosis can occur within them. The driving force for the movement is transpiration, or evaporation of water from the leaves through the stomata. This creates low pressure in the leaves causing water to be sucked up the stem to replace the lost water. Because of water's unique property of cohesion, it can be "pulled up" through the stem and leaves in an unbroken stream. This is called the transpiration stream. (See unit 2, "Soil Water Management" for an explanation of the properties of water.)

As the water and nutrients pass into the leaves, they diffuse from the xylem into leaf veins. These veins transport the water and nutrients to the leaf cells where they are absorbed by through the same processes that the root cells used to absorb them into the plant to begin with. The water that is turned into vapor by the heat energy from the sun moves out of the plant through the stomata. This heat from the sun is the source of energy for all water movement in plants.

Far more water passes through a plant by way of the transpiration stream than is used. Only 1% of the water absorbed is used by the plant cells for photosynthesis and retained in the plant. The remaining 99% evaporates from the leaves and is lost to the atmosphere. In the evening, most plants continue to absorb water, usually more than they transpire. This causes a build-up of water in the plant tissues.

There are a number of factors that affect the rate of transpiration in a plant. These are light, temperature, humidity and air movement. The stomata of a leaf react to light. They open when light strikes the leaf and close in darkness, causing the plant to lose water during the day.

The air temperature and radiant heat from the sun heating a plant's tissues also affects the rate of transpiration. As the air temperature increases and the plant's tissues are heated by radiant energy, water within the leaves turns to vapor faster and exits the plant through the stomata. This "pulls up" water from the roots at a faster rate, increasing the flow of water through the plant. If the plant gets overheated, it will wilt as a self-protective measure. Plants will wilt under these conditions even with sufficient water available in the soil.

Humidity of the atmospheric air also affects the rate of transpiration. Humidity is the amount of water vapor that atmospheric air can hold at a given temperature. When the humidity is high, there is less potential for the water vapor to diffuse into the air because it is already close to saturation. In low humidity conditions, a plant will lose more water vapor because there is a greater potential for the air to absorb it.

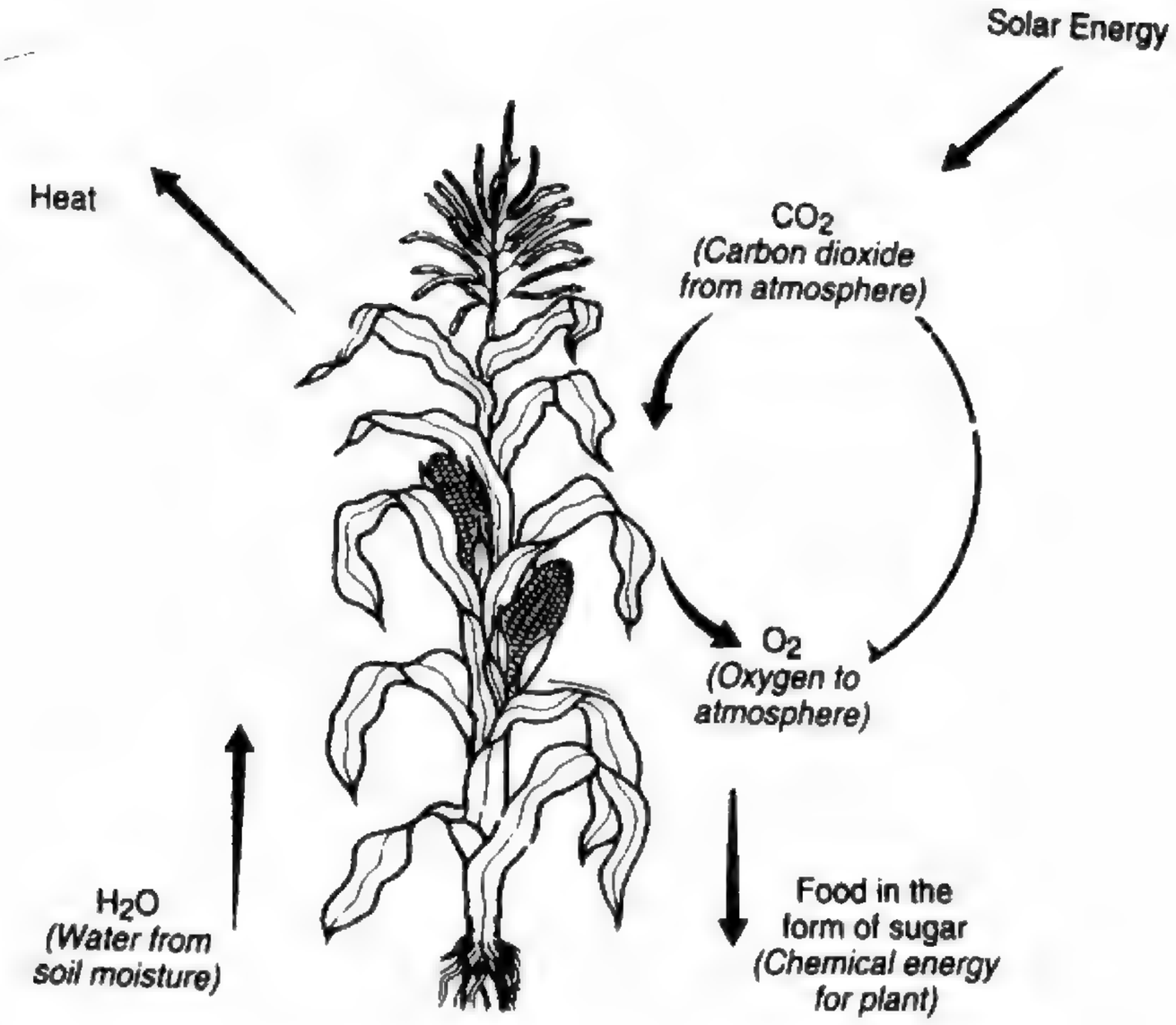
Air movement, or wind, is a major factor in water vapor loss from plants, increasing the rate of transpiration. Plants must keep the cells just inside the stomata moist so they can absorb the carbon dioxide necessary for photosynthesis. To do this, the leaves are slightly concave on the underside. This traps some of the water vapor escaping the plant through its stomata, forming what is called a "boundary layer" of near 100% humidity. A boundary layer is only a few millimeters thick or less. This high humidity boundary layer closely matches the humidity of the cells in the leaf and slows the plants' transpiration.

When the wind blows, the boundary layer is reduced or blown away. In conditions of no wind there will be a thicker boundary layer and slower transpiration. With increasing wind, the layer will get thinner and transpiration will be more rapid. At high wind speeds, the stomata usually close to prevent the rapid water loss from the plant.

PHOTOSYNTHESIS

Photosynthesis is the process by which plants make their own food. This process starts in the chloroplasts. These structures are contained within the plant's cells. A single cell may contain as many as 50 chloroplasts. The chloroplasts contain chlorophyll, a magnesium based molecule. This molecule has the unique ability to both absorb light energy and react with CO_2 and H_2O.

Photosynthesis



Carbon Dioxide Water Solar Energy

$6CO_2 + 12H_2O + Light \longrightarrow$

Glucose Water Oxygen

$C_6H_{12}O_6 + 6H_2O + 6O_2$

The chemical formula for photosynthesis is:

$$6\ CO_2 + 6\ H_2O \rightarrow 6\ O_2 + C_6H_{12}O_6$$

Since most people don't speak "Chemicalese," we can write this as:

6 molecules of water plus 6 molecules of carbon dioxide
(In the presence of sunlight and chlorophyll)
Produce 1 molecule of sugar plus 6 molecules of oxygen.

This is a simplified explanation of photosynthesis. It is a much more complex process that starts with the production of a hormone, ATP (adenosine triphosphate). ATP is a molecule that provides the energy for combining CO_2 and H_2O to make glucose, the 6-carbon sugar in the above formula. Glucose is a mobile form of sugar. It can be transported all through the plant by way of the phloem and used for energy. It also serves as a building block to make polysaccharides, other monosaccharides, fats,

amino acids, nucleotides, and all the carbon-based molecules the plant requires.

The chemical reactions that are directly dependent on sunlight (making ATP and glucose) are called "light reactions." Those that do not require sunlight but use photosynthate for energy are called "dark reactions." (Recent research has shown that some dark reactions are indirectly stimulated by sunlight, but these terms are still used with that understanding.)

TRANSPORT OF GLUCOSE

The "source and sink" concept is used to describe the way a plant makes and distributes the glucose. The "source" is the leaves in most plants. Glucose is made in the chloroplast and transported into the phloem. The phloem then transports the glucose to other areas of the plant for storage and later conversion.

The glucose is then stored in the vacuoles in the plants' cells. (Plants may also store sugar in tubers, fruit and other structures.) These storage spaces are called "sinks." Once all the sinks are filled, a hormone is released as a chemical signal for the plant to start making the other chemical compounds that are needed for food and growth.

This whole cycle starts early in the morning as part of the plant's endogenous rhythm. This is similar to the internal mechanism that wakes us up each morning at the same time. It's commonly called our "body clock." This can be upset by "jet lag" or traveling across time zones too fast for our bodies to adjust to the change in sun time. It can also be upset by changing our sleeping and waking times suddenly. Plants' endogenous rhythms also are upset by rapid changes in sun time.

Plants' endogenous rhythms are set to start their cycles before daylight. They prepare for photosynthesis in the predawn hours by shutting down all other activity in the leaf cells that contain chloroplasts. They are prepared for the first rays of sun at dawn to begin photosynthesis. After this, they rely on feedback from the other cells to tell them when to change processes.

The endogenous rhythm of plants was discovered by placing plants in a completely dark room and monitoring their cycles. All the plants changed cycles in the early morning in anticipation of light. They continued this way for 3 to 4 days before their rhythms became erratic. Interestingly, this is about the same amount of time it takes for human endogenous rhythms to become disrupted by total darkness.

PLANT HORMONES

A hormone is any chemical produced in one part of a body, transported to another, causing a response. Hormones act as control chemicals in multi-cellular organisms.

Plant hormones function as general growth stimulators or inhibitors. Unlike animal hormones, plant hormones are not produced in definite organs and do not have specific target tissues. Plant hormones interact with one another in complex ways to produce the mature, growing plant.

Five major classes of plant hormones have been extensively studied and are reasonably well understood. However, others exist which we see the effects of but have not been isolated. The five we do know of are auxin, cytokinin, gibberellin, abscisic acid and ethylene.

Auxin causes several responses in plants. Among these are bending toward a light source (phototropism), downward root growth in response to gravity (geotropism), flower formation, fruit set and root growth.

Gibberellins stimulate cell division and elongation, break seed dormancy, and speed germination.

Unlike other hormones, cytokinins are found in both plants and animals. In plants they stimulate cell division, growth of lateral buds and the formation of chloroplasts.

Ethylene is unique in that it is found only in the gaseous form. It induces ripening, causes leaves to droop and drop (abscission), and promotes maturation and death. Plants often increase ethylene production in response to stress, and ethylene is found in high concentrations within cells at the end of a plant's life. The increased ethylene in leaf tissue in the fall is part of the reason leaves fall off trees.

Abscisic acid (ABA) is a general plant-growth inhibitor. It induces dormancy and prevents seeds from germinating. It also causes abscission of leaves, fruits, and flowers. ABA also functions to regulate transpiration by causing the stomata to close. High concentrations of ABA are present in guard cells during periods of drought stress and probably play a role in stomatal closure under these conditions.

PLANT NUTRIENT UPTAKE

Plants absorb nutrients through two structures: roots and leaves. The leaves absorb carbon dioxide and the roots absorb all the other nutrients. Carbon dioxide is the basic building block for all organic compounds

produced by plants. This is absorbed from the air through the stomatal openings in the leaves.

Each stoma (singular for stomata) has two guard cells, one on each side of the opening. These act to open and close the stoma in response to signals from the plant. The guard cells swell to close the stoma and shrink to open it. The stomata are opened before sunrise to prepare the plant for water absorption through the transpiration stream and to be able to absorb carbon dioxide from the atmosphere. The stomata close during the evening or if the plant comes under stress from drought or high winds.

Since all the carbon a plant uses for energy and growth is absorbed through the stomata, it is advantageous for the plant to have sufficient water available near the roots to avoid the closing of the stomata. Water is absorbed by plants through fine structures on roots called root hairs. They do this through the process called osmosis. Once the water enters the roots it moves through the root cells primarily by this same process. This absorption of water is important because it is also the pathway for plant uptake of soluble salts like nitrates.

Plants absorb mineral nutrients through their roots by two processes. The first, as noted above, is through the absorption of water containing soluble nutrients. The second is by direct absorption of ions from the soil. This is an energy demanding process. Roots must have photosynthate (ATP and sugar) present in the root and oxygen available around the root for ion absorption.

Plants can also absorb large, complex molecules such as hormones and vitamins directly from the soil. This is done through open spaces in the covering of the root structures that are filled with proteins. These openings let in specific molecules at specific sites.

SUMMARY

Water moves from roots to leaves through the xylem vascular tissue, powered by the energy of the sun. As a molecule of water is evaporated from the leaf, it pulls the next molecule up to take its place because of cohesion of the water molecules. Conditions that speed up the evaporation of water, such as wind, light, warm temperatures, and low humidity will speed up transpiration.

Plants make their food in the chloroplasts of the plant's cells by changing water and carbon dioxide into glucose and oxygen with the power of the sun and the pigment chlorophyll. The glucose made in photosynthesis

moves through the phloem vascular tissue from the "source", into the leaves toward the "sink" of the vacuoles in plant cells or other storage structures.

Plant hormones function as general growth stimulators or inhibitors. The five major classes of plant hormones are auxins, gibberellins, cytokinins, ethylene and abscisic acid.

Carbon dioxide is absorbed by diffusion through the stomata of the leaves. Water and nutrients move into the root hairs by osmosis. Plants have special abilities to absorb ions, hormones and vitamins from the soil.

PLANT FAMILIES

Plants are identified and grouped by like characteristics. Scientist give each organism a Latin name for species and genera. Each organism is then put in a family. These family members will have many characteristics alike which means they are attractive to the same insects and pests. Often there will be common names for the organisms, as well as scientific names, but sometimes two different organisms may be called the same common name.

Knowing the families of the farm's crops is essential for crop rotations and good planning. To avoid build up of specific pests and diseases, crop families should be rotated. Growing all the crops of a given family in one block helps to plan rotations. Crops should be rotated so the same family will not be grown in the same soil for several years. Some recommend that the best rotation is 8 years, but shorter rotations can also work.

Agricultural Crop Families

Chenopodiaceae	*Cucurbit*	*Brassica*	*Legume*	*Apiaceae*
Chard	Cucumber	Broccoli	Beans	Parsley
Spinach	Squash	Cabbage	Peas	Celery
	Pumpkin	Kale	Soybeans	Parsnip
	Cantaloupe	Radish	Peanuts	Dill
	Gourds	Cauliflower		
	Watermelon	Turnips		
		Arugula		
		Collards		
		Mustard		

Solanaceae	*Poaceae*	*Liliaceae*	*Asteraceae*	*Hibiscus*
Tomatoes	Corn	Onion	Lettuce	Okra
Potatoes	Popcorn	Garlic		Cotton
Peppers		Shallots		
Eggplant		Leeks		

Convolvulaceae

Sweet potato

PLANT LIFE/SOIL LIFE RELATIONSHIPS

As our knowledge of plant and soil life has expanded, their relationships have become more evident. These relationships are as complex and varied as the life itself. Discoveries have also been made recently about how plants can manipulate their environment for their own benefit.

Objectives:

1. *Describe the 3 types of symbiotic relationships.*
2. *Explain the legume-rhizobia relationship and the myccorhizal relationship.*

PLANT/SOIL RELATIONSHIPS

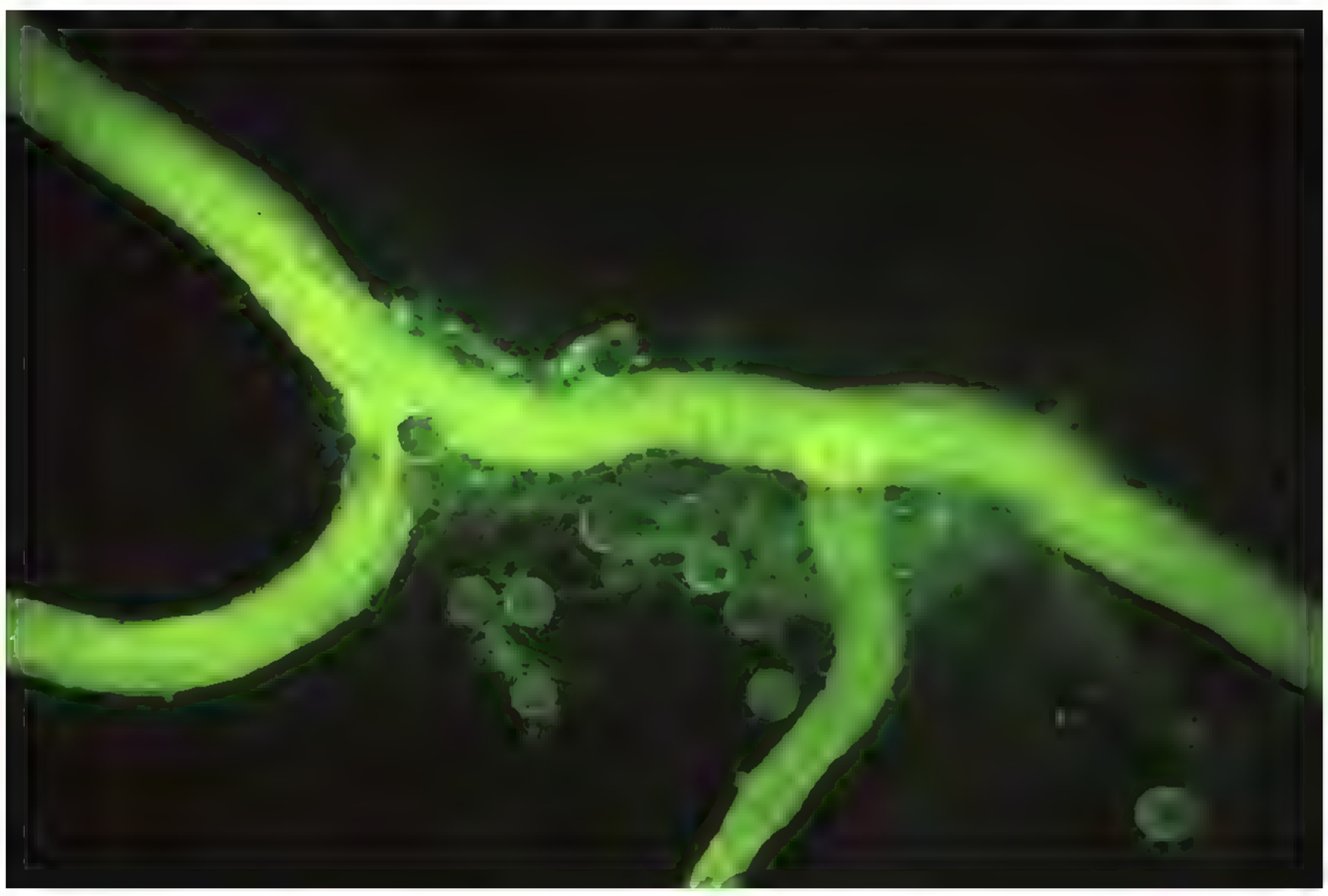
All life forms interact with other life forms. Most of the interactions between species involve food. Their interactions can be competing for the same food supply, eating or avoiding being eaten. These interactions are usually brief and one species winds up as food for the other.

But there are many cases where two species live in close association over long periods of time. Such associations are called symbiotic or "living together." In symbiosis, at least one member of the partnership benefits from the relationship. The other member may be injured or fed upon, relatively unaffected, or may also benefit.

An example of a symbiotic relationship where one species is injured is parasitism. This is a relationship where one species feeds on the other, making it weaker. A relationship where one species benefits from the interaction and the other is unaffected is called commensalism. A relationship where both species benefit is called mutualism. The term "symbiosis" has been commonly used as a synonym for mutualism. Examples of how plants form mutual relationships with other species are provided by rhizobial bacteria and mycorrhizal fungi.

Legumes have the ability to form a mutual relationship with rhizobial bacteria. In this relationship the bacteria live in nodules in the plant's roots. The plant feeds the bacteria sugars and carbohydrates it makes. The bacteria in turn convert non-usable forms of nitrogen into nitrates that the plant can use.

Most plants, including those grown as food and fiber crops, form mutualistic relationships with mycorrhizal fungi. The fungi grow their fibers into the root structures of the plants. They grow through large volumes of the soil and provide the plant with water and minerals they absorb. The plants feed these fungi sugars and carbohydrates in return.



MANIPULATION BY PLANTS

Recent research into plant and soil life relationships has shown that plants can manipulate their environment to their benefit. An example of this is the mutual relationship between legumes and rhizobial bacteria. Until

recently it was thought that the bacteria "infested" the roots of the legume and that the plants accommodated them by growing nodules. However, research has shown that when a root of a legume encounters rhizobial bacteria in the soil, it grows nodules around the bacteria, "capturing" them. In soil where sufficient nitrate is present for the plants, legumes will stop feeding the bacteria and the colonies will go dormant.

We have also learned that plants encourage large colonies of beneficial bacteria around their roots by exuding photosynthate out of their roots and into the soil. These bacteria cycle nutrients in close proximity to the plant's roots, making them easily obtainable for the plant. They also encourage bacteria that protect the plant from fungal attack in this way.

SUMMARY

Symbiotic relationships are close relationships between two living organisms over a long period of time. These relationships are either mutually beneficial or beneficial to one and either neutral or detrimental to the other. Mutualism, commensalism and parasitism are the words used to describe these relationships. The legume-rhizobia relationship is mutual because the legume gets nitrogen released by the rhizobia and the bacteria gets sugars produced by the plant. Mycorrhizal fungi also feed on the sugars from the plant and provide the plant with water and nutrients. The relationships between plants and soil are complex and we are discovering more each day how the plant manipulates the soil organisms for its own good.

UNIT SUMMARY

The roots, stems, leaves, flowers and fruits of plants are connected by the vascular tissue through which the sugars, water, and other nutrients flow. Energy from the sun powers both the movement of water up the stem of a plant and the production of glucose in photosynthesis. The sugars move through the plant along a concentration gradient from "source" to "sink".

Plant hormones function as general growth stimulators or inhibitors. Plants may have close associations with other organisms called symbiotic relationships. Myccorhizae and legume-rhizobia relationships are beneficial to the plant by making nutrients more available.

LESSON PLANS WITH OBJECTIVES - PLANTS

I AND II. PLANT ANATOMY

OBJECTIVES:

5. Identify the basic structures of plants.
6. List the 3 tissue types of plants and the general function of each.
7. Name the substances that flow through the xylem and those that flow through the phloem.
8. List 4 ways plant and animal cells differ.

LESSON PLANS

1. Show the video on Riverview Farms and discuss the focus questions
2. Display **a variety of plants** to introduce the diversity of plants. Use these plants to describe the external structures of a plant.
3. Use Unit 3 power point presentation slides 1 – 11 to identify the various plant structures, both external and internal.
4. Student activities:

Plants disassembled learning activity – Give each team of students a bag of plant parts that you have prepared. The bag should contain leaves, pieces of stem, pieces of roots, flowers, and fruits. Have students sort the pieces by type of structure. Ask them to analyze what characteristics they used to classify each category. Relate those characteristics to the function of each particular plant part.

Worksheet on plant cells versus animal cells- Have each student draw a plant and animal cell, on the worksheet, putting in only those structures which are different between those cells.

III. PLANT PHYSIOLOGY

OBJECTIVES:

9. Describe how water moves from roots to stems to leaves.
10. Identify 3 factors which will effect transpiration.
11. Define photosynthesis and state the location of the process.
12. State the formula, in words, for photosynthesis.
13. Name the plant structure which is the "source" of glucose and the structure which is the "sink".
14. Define endogenous rhythm.
15. Name 5 classes of plant hormones and the general effect they have on plants.

16. Describe how carbon dioxide, minerals, and water are each absorbed by plants.

LESSON PLAN:

1. Use Unit 3 power point presentation slides 12 - 38 to present the information on plant physiology.
2. Include these demonstrations:
   a. Celery stalk in glass of water with food color to show uptake of water through the xylem
   b. A small chain to help students visualize how water molecules move up the xylem as they are pulled by the water molecule above them. Be sure to emphasis that it is the power from the sun evaporating the molecules from the stoma.
3. Use the **worksheets** on comparing vascular tissue in an animal and plant to help students grasp the differences.
4. Have students draw a plant and label the points of entry of water, nutrients, and carbon dioxide. They could also use different colors to indicate the direction of movement of water and sugars.
5. As you show the slides on plant hormones, have the students fill in the **Plant Hormones Worksheet**.

III. PLANT LIFE/SOIL LIFE RELATIONSHIPS

OBJECTIVES:

3. Describe the 3 types of symbiotic relationships.
4. Explain the legume-rhizobia relationship and the myccorhizal relationship.

LESSON PLANS:

1. Use Unit 3 power point presentation slides 39-42 to present material on plant life – soil life interactions.
2. Display some **Spanish moss on a branch, a clover plant (including roots), and a diseased plant**. Describe the three types of symbiotic relationships and have students determine the two organisms involved in each, and what type of symbiotic relationship each has.
3. **Use illustrations of rhizobia and mycorrhiza** to describe the rhizobial relationship with legumes and the mycorrhizal relationship. Tell how forest trees will not grow without their mycorrhiza.

Video Focus Questions – Riverview Farms

1. How did the Swancy's get started in organic farming?
2. What basic abilities are required to be successful?
3. What does Wes see as the advantage of being a farmer?
4. How does Riverview market their produce?
5. How do they use the computer?
6. What are their future plans for the farm?

PLANTS DISASSEMBLED

Purpose: To distinguish the different parts of a plant and to infer the function of that part from its characteristics.

This activity can be done in the classroom. Before the class, bags of plant parts should be assembled, one for each team. Use weeds, spent greenhouse plants or any available plants and cut up into leaves, stems, leaves, flowers and fruit. Put an assortment into each bag.
Directions:

1. Each team gets one bag. Dump the contents of the bag on the table and sort the contents into roots, stems, leaves, flowers and fruit. Plant parts may not be complete, but only a piece of the whole.
2. Look at each pile and determine what characteristics were used to put it in a particular category. Record in the chart.
3. Think about the characteristics you recorded and what the relation they have to the function of that particular plant part. Record in the chart.

	Characteristics	**Functions**
Roots		
Stems		
Leaves		
Flowers		
Fruits		

Questions:

1. What relationship was there between the characteristics of roots and the function of roots?

   Of stems?

   Of leaves?

Of flowers?

Of fruits?

2. Name a common vegetable that we eat that is in each of these categories.

PLANT CELLS VERSUS ANIMAL CELLS

List the differences between plant and animal cells, then state the function of the plant or animal that accounts for the difference.

Difference	**Function**	
	Plant	**Animal**
1. cell wall	support/no skeleton	
2. _____	_____	_____
3._____	_____	_____
4._____	_____	_____

Sketch of a Plant Cell

Sketch of an Animal Cell

PLANT HORMONES

State the function of each hormone in a plant and then draw a sketch of the effect the hormone has on the plant, such as elongated stems, etc.

Plant Hormone **Function of Hormone in the plant**

1. Auxin _____

Illustration

2. Cytolkinins _____

Illustration

3. Abscisic acid _____

Illustration

4. Gibberellin _____

Illustration

5. Ethylene _____

Illustration

VASCULAR TISSUE

Fill in the blanks with the best description for vascular tissue in either a plant or animal.

Characteristic	**Plant**	**Animal**
1. Location	_____	_____
2. Direction of flow	_____	_____
3. Composition of liquid	_____	_____
4. Types of tubes	_____	_____
5. Function of liquid	_____	_____
6. Living or dead cells making up walls of tube	_____	_____
7. Force that causes movement	_____	_____
8. Type of partition within the tube	_____	_____

UNIT 4 – PLANT APPLICATIONS

I. INTRODUCTION

II. SEEDS AND SEED GERMINATION

1. Seeds
2. Seed Germination Factors
3. Effect of Humic Acids on Germination

III. PLANT PROPAGATION

1. Seed Propagation
2. Propagation from Cuttings
3. Other Propagation Methods

IV. TRANSPIRATION STREAM APPLICATION

V. UNIT SUMMARY

INTRODUCTION

Organic vegetable growers use transplanted seedlings to grow many crops. The benefits of transplants include earlier planting, accurate spacing, and getting ahead of the weed seed that will germinate at the time of planting. Reasonably priced organic transplants are not readily available, so most farmers grow their own.

Most vegetable crops are grown from seed but many fruit crops are produced from asexually propagated plants. Knowledge of both methods of reproduction is important to establishing an organic farm.

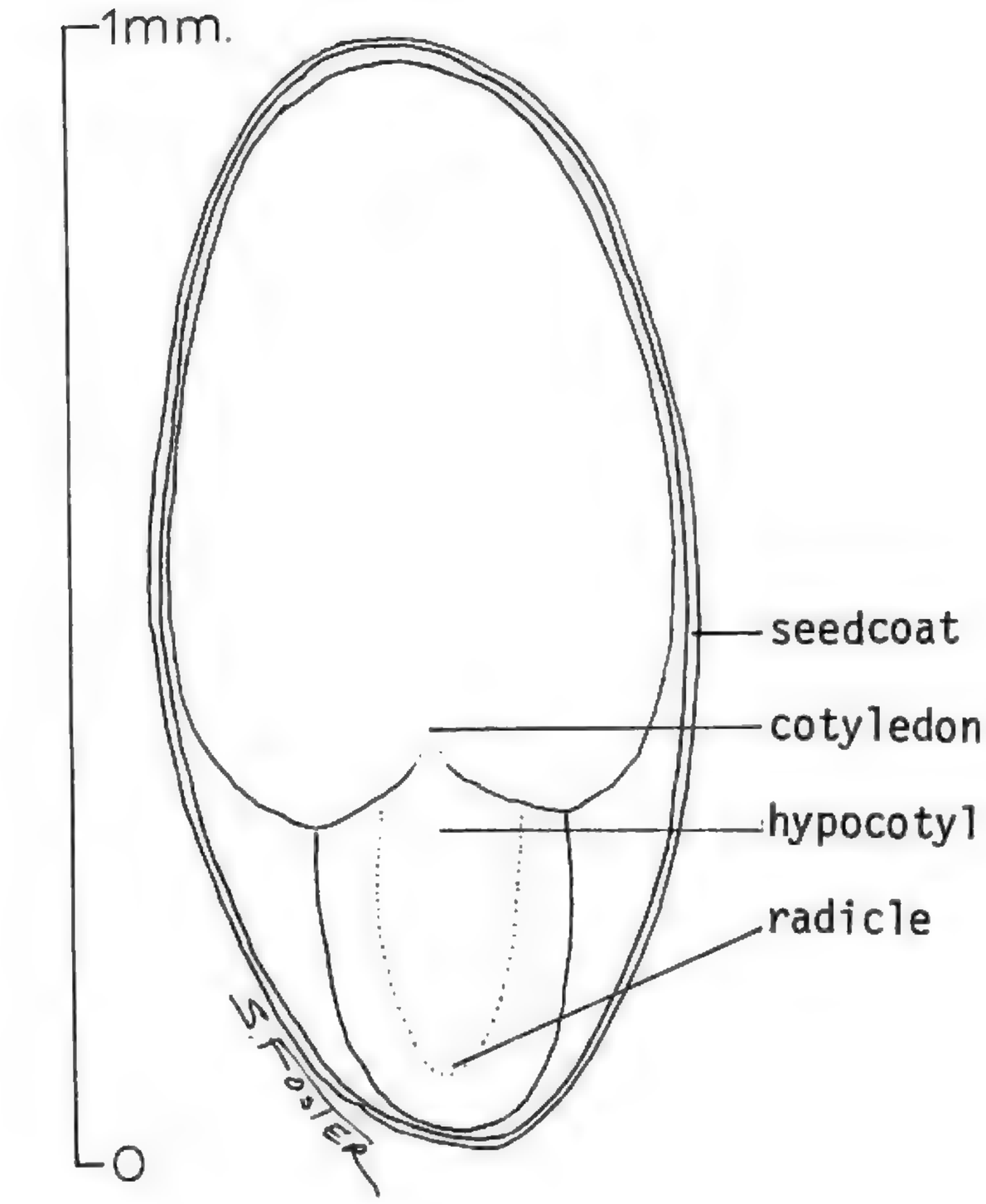
SEEDS AND SEED GERMINATION

Objectives:

1. *Describe the structure and formation of a seed.*
2. *List the three requirements for germination of most seeds.*
3. *State the effect of humic acids on germination and where they can be found.*

SEEDS

Plants reproduce by making seeds. The seeds are a storehouse for the plant's offspring, waiting for the right conditions to begin growing. They have a husk or outer covering, a germ or living embryo, and food stored to get the plant started.



Suzanne Foster @USDA-NRCS PLANTS Database

Seeds are formed inside the flowers of plants when pollen from the same plant or another plant lands on the part of the flower that contains the ovum or egg. This starts the growth of the embryo and the formation of the seed. The embryo grows to a certain point inside the seed covering and then stops. This cessation of growth is called dormancy. Dormancy begins when the seed has finished forming on the plant and the embryo has developed a radicle or embryonic root and one or two cotyledons or embryonic leaves. Many of the seeds used in agriculture have no dormancy requirement. They will sprout under the right conditions as soon as they mature.

SEED GERMINATION FACTORS

Germination is the resumption of growth of the plant embryo within the seed after a period of dormancy. The first visual sign of germination is

when the radicle bursts through the seed coat and protrudes as a young root. Seeds germinate or sprout if the right conditions are present. Most seeds need three things to begin sprouting:

- Light
- The right amount of moisture
- The right temperature

Light is important in stimulating seed germination. All seeds need some amount of light exposure to start sprouting. For some seeds, all it takes is a flash of light. This can happen, in the case of weed seeds, when we plow or cultivate. The seeds are exposed to a flash of light when soil is disturbed. Others require constant light to stimulate germination. An example of this is lettuce seed.

A myth about seeds that need constant light to stimulate germination is that they have to be placed on the surface of the soil or planting mix and left uncovered. Enough light can penetrate through soil and soil mixes below the surface to stimulate seeds to sprout. If they are buried below this penetration zone, however, they will not receive enough light. One of the problems with surface sowing is that the seeds may dry out because there is not have enough moisture on the soil surface to stimulate germination.

The right amount of moisture is another requirement for germination, If there is too much or too little moisture present, most seeds will not germinate. Plants used as agricultural crops mostly fall into a group requiring the same amount of moisture for their seeds to germinate. This requirement is moist but not so wet that the seed has water all around it. They can also be moistened and begin the germination process even if they dry out again. Some seeds, like parsley and carrots, require a long period of a week or more of constant moisture to germinate. If the seeds are moistened and then dry out or if they go through a wet and dry cycle, they will not germinate well or at all.

The third requirement for germination is the right temperature. This varies from plant to plant. For instance, spinach has a much lower germination temperature than tomatoes. Temperature stimulates the seeds to germinate in the season to which they have become adapted.

There is an optimal temperature for each kind of seed. At this temperature more seeds germinate and at the same time. However, the temperature can be slightly higher or lower and still stimulate the seed. Some seed catalogues show this range as a chart, as well as the optimal germination temperature.

There are some seeds that need special conditions for germination, like scoring of the seed husk or a number of cycles of freezing and warm

temperatures. Seed companies sometimes prepare seeds for fast germination by performing these procedures before the seed are sold.

EFFECT OF HUMIC ACIDS ON GERMINATION

Recent experiments have shown that humic acids stimulate faster germination of seeds. In these experiments, humic acids were extracted from organic matter and mixed with water. This solution of water and humic acids was used to water seeds planted in flats. These seeds sprouted faster than those planted in the same way but without humic acids in their water. The seeds treated with humic acids also had a higher germination rate. There is no explanation yet of how this works, but it is possible to use this information in starting seeds.

Finished compost is high in humic acids if it has not been exposed to high rainfall that would leach them. Sifted compost can be used to cover seeds in flats to stimulate germination. Seeds sown in beds and rows can be covered this way, also. This puts the seeds in direct contact with the compost. The compost will also act as a mulch cover for the seeds. The soil surface where the seeds are sown will stay moist longer and this will also aid in germination.

SUMMARY

Seeds are the plants' offspring. They develop when the ovum in the flower is fertilized by pollen. A mature seed contains an embryonic root, called a radicle and embryonic leaves called cotyledons. There is an outer protective cover around the embryo and stored food for it to live on until it starts to make its own food. Some seeds have a certain dormancy requirement before they can germinate, but most agricultural seeds do not.

PLANT PROPAGATION

Objectives:

1. *List three benefits to starting seeds in flats in a greenhouse.*
2. *Describe three ways to get an acceptable organic soil mixture.*
3. *Identify the hormone important in stimulating rooting of cuttings and where it can be found.*
4. *List three other ways to asexually propagate plants.*

Normal plant propagation takes place through sexual reproduction. The plant's flowers produce seeds and these produce new individuals. There are also asexual propagation techniques that are used to produce more plants. These techniques use tissues or parts of plants to start new ones. Asexual methods produce plants that are identical to the original one. They are used primarily for woody perennials like berries and nursery crops or ornamentals, but some are used for agricultural crops.

SEED PROPAGATION

Almost all agricultural crops are started from seeds. These are planted either in fields or beds (direct seeded) or in flats and the young plants are transplanted later. Some plants do better if direct seeded, like root crops, beans and peas. However, most can be transplanted after starting in flats.

There are benefits to starting seeds in flats or containers indoors or in a greenhouse. The first of these is that the best conditions for germination can be created for each type of seed. There is no way to control soil temperature in fields unless some type of cover is placed over planted areas. In addition, it's much easier to control the moisture in a greenhouse. Another benefit is that plants can be started before outdoor temperatures are suitable for the crop.

One of the challenges of starting seeds indoors in an organically certified operation is finding a "starting mix" that is acceptable under the standards. This is because most locally available mixes contain chemical fertilizers and other substances that are prohibited. Local sources for acceptable mixes are scarce in most areas. This means that shipping costs make acceptable mixes that are commercially available expensive.

However, organic growers can make their own mixes for low or no cost. Custom mixes can be made from acceptable materials like peat moss and perlite. Organic "starter" fertilizers and minerals can be added to these as solids when mixed or in dissolved form in water after planting the seeds. These types of "sterile" or "soiless" mixes are usually required for resale of plants.

If all the plants are for use on the farm where they're started, a mixture containing soil can be used. To make a soil mix, select some soil from a fertile area or field. The soil can be used in flats and cells without additions. If used this way, it will help to cover the seeds with sifted compost. This will stimulate germination while acting as mulch to hold moisture in the flats or cells.

In the case of sandy soil, a mixture of 50% sandy soil and 50% sifted compost works well. This ratio will improve the mix's water holding

capacity, reducing the number of times seedlings will need to be watered each day. A high clay content soil may require addition of some organic matter to help it drain. This can be either compost or peat moss. If the soil is rocky or contains clods, it should be screened or sifted before using for plant starting.

A sifter of any size for both soil and compost can be made by constructing a wooden frame. Wheelbarrow-scale sifters can be made from 1x2 or 2x2 boards. These can be nailed or screwed together and hardware cloth attached as the screen.

The main disadvantage of using a mix containing soil is that weed seeds will be in the soil and will sprout soon after the crop seeds. Hand weeding can eliminate these easily, but takes time and some care. Also, the weeding needs to be done before the weed sprouts grow so much root mass that pulling them will disturb the crop roots.

PROPAGATION FROM CUTTINGS

Plants have three basic structures with different tissues: roots, stems, and leaves. However, most plants have the ability for one of these structures to grow the tissues of another. This ability enables us to grow plants from different tissues removed from the parent plant.

An example of this is the ability of plants to grow roots from their stem tissues. The plants do this when we place a cutting from a plant containing stems and leaves into soil or some other rooting medium. If the plant has this ability and there is sufficient water and nutrients available, the cutting will grow root tissues where there were none.

Auxin is the active ingredient in most rooting compounds in which cuttings are dipped during this type of propagation. This ensures that the plant being rooted has an abundance of this hormone to stimulate growth of root tissue. Plant hormones that stimulate this are abundant in willow tree tissue. This is why they're so easy to root from cuttings. It's possible to make an extract from willow branches by cutting them up and soaking in water. This "willow tea" is used to water cuttings after placing them in the rooting medium.

OTHER PROPAGATION METHODS

Other methods of propagation include layering, separation of bulbs and tubers and tissue culture. Layering causes roots to develop on shoots that are still attached to the parent plant. The stem is not cut from the main plant until it has rooted. This method is a good propagation choice when only a few plants are needed.

Simple layering is done by bending a branch to the ground and burying a portion of it, leaving the tip uncovered. Hold the branch in place with a rock or peg. Layering is usually done in early spring while plants are still dormant or in late summer on wood that has not become woody. Plants with flexible branches are particularly suited to this method.

Plants can be propagated from tuberous roots. This type of propagation involves cutting the tubers into pieces so that each piece has at least one eye or bud. An example of this is cutting up potatoes before planting to increase the number of plants from a quantity of seed potatoes.

Tissue culture is a type of asexual reproduction. Each plant cell has the potential to grow into a new plant exactly like the parent. This fact coupled with technical advances, specialized equipment and sterile laboratory conditions has led to tissue culture. In tissue culture, individual or small groups of plant cells are manipulated so they each produce a new plant. A tiny piece of bud, leaf, or stem can produce incredible numbers of new plants in a small space in a short time. However, there are some problems with spontaneous mutations that naturally occur. In tissue culture, the incidence of these mutations is much greater than through other methods of propagation.

Conditions for tissue culture are very exacting. Sterile conditions must be maintained. Temperature, light, humidity, and atmosphere are strictly controlled with electronic sensors and computerized controls. Such costly equipment rules this out for most farm operations.

SUMMARY

Seeds are used to start most agricultural crops. They may be directly sown in the field or started in the greenhouse in flats and later transplanted to the field. Organic soil mixes may be bought or made, but care must be taken to make sure they do not have chemical fertilizers added. Peat and perlite are basic ingredients for most mixes. Mixes containing soil can be used but weed seed may be a problem.

TRANSPIRATION STREAM APPLICATION

Objectives:

1. *Describe why wilting occurs in young tender plants like lettuce, when there is water available to the roots.*
2. *Identify a method to prevent wilting.*

Another application of plant physiology that we can use to enhance plant growth has to do with understanding the transpiration stream. Some plants wilt easily. These are usually tender plants that are grown for their leaves like lettuce. These tender plants don't have the ability to tolerate heat as well as most other crops. They wilt even with sufficient water present near their roots. This is because they lose water through evaporation faster than their roots can absorb it in an attempt to cool themselves. This more rapid loss of water "breaks" the transpiration stream and stops the flow of water through the plant.

Wilting under these conditions can be avoided through the type of irrigation used. Wilting of crops when sufficient water is available is common when drip irrigation is used. Overhead irrigation, timed to cool the plants before temperatures become critical, will cool the plants' tissues and prevent wilting. This will also rapidly revive already wilted plants. Overhead irrigation or misting can be combined with drip, using the drip to supply water to the roots and overhead to cool at timed intervals. Use of a gentle spray nozzle on a hose can be used for small operations.

SUMMARY

Some plants will wilt when there is plenty of water available to the roots because they are losing water so rapidly from the leaves that the transpiration stream is broken and water can no longer be brought up from the roots. Cooling the plants with overhead irrigation can prevent this problem.

UNIT SUMMARY

Seeds are the way plants reproduce and they contain the structures necessary to make a new plant within a seed coat filled with stored food. Some seeds need a period of dormancy before they can germinate. Germination starts with the absorption of water and the eruption of the radicle from the seed coat. Light, moisture and the right temperature are necessary for seeds to germinate. Humic acids seem to promote germination of seeds.

Plants can be propagated by sowing seeds in flats in a greenhouse or directly in the field. Care must be taken to use an organic seed starting mix if growing in the greenhouse. Some plants can be propagated using asexual methods such as layering, rooting stems, dividing tubers and tissue culture.

Knowledge of how the transpiration stream works allows for techniques to prevent wilting in plants that transpire very rapidly from large leaf surfaces.

LESSON PLAN WITH OBJECTIVES – PLANT APPLICATIONS

I. AND II. SEEDS AND SEED GERMINATION

OBJECTIVES:

4. Describe the structure and formation of a seed.
5. List the three requirements for germination of most seeds.
6. State the effect of humic acids on germination and where they can be found.

LESSON PLANS:

1. Use Unit 4 power point presentation slides 1-8 to discuss the structure of a seed and the factors which effect germination.

2. Have a **variety of seeds** displayed at the front of the room. Hold up various seed and ask students to identify. Be sure to include some big seeds like avocado.
3. Cut open one of the large seed and talk about the seed parts. Pass the seed around the room. Use the **picture of the seed** to help students identify the parts.
4. Ask students if they have seen seed that have started to germinate inside the fruit. Talk about dormancy requirements for some seed.
5. **Labs - Effect of light on germination, Effect of moisture on germination and Effect of temperature on germination**. Discuss the results with the students.
6. Have students design an experiment to measure the effect of humic acids on germination. Carry out the experiment if possible.

II. PLANT PROPOGATION

OBJECTIVES:

5. List three benefits to starting seeds in flats in a greenhouse.
6. Describe three ways to get an acceptable organic soil mixture.
7. Identify the hormone important in stimulating rooting of cuttings and where it can be found.
8. List three other ways to asexually propagate plants

LESSON PLANS:

1. Ask students to identify three important factors in germination they learned in the last lesson. Ask how these factors can be controlled to get the best germination. Use their answers in a discussion of the advantages of starting seed in the greenhouse.
2. Use Unit 4 power point presentation slides 9-22 to introduce sexual and asexual propogation, and soil mixes.
3. Have a **bag of commercial sterile seed starting soil mix** at the front of the room. Read the label that tells the contents. Ask students if this would be suitable for an organic operation.
4. Have students look up the price for organic seed starting mixes, including the shipping. This can be done from **catalogs** you have available or the internet. Have them compare the cost with the cost of home-made soil mixes.
5. **Lab – soil mixes**
6. Demonstrate taking **a stem cutting from a house plant**.
7. Demonstrate **cutting a potato tuber into two pieces,** each with an eye as another method of asexual reproduction.
8. **Demonstrate layering** to discuss this method of reproduction.
9. Explain tissue culture.
10. The **powerpoint presentation Asexual propagation lab** presents a simple lab of taking 4 types of cuttings.

III. TRANSPIRATION STREAM APPLICATION

OBJECTIVES:

3. Describe why wilting occurs in young tender plants like lettuce, when there is water available to the roots.
4. Identify a method to prevent wilting.

LESSON PLANS:

1. Review the transpiration stream and ask students to visualize what would happen if the water lost by a large leaf surface like a lettuce leaf was greater than the water taken in by the roots.
2. Ask students what could be done to slow the transpiration stream, having them recall that the stoma open to take in carbon dioxide, but in the process they also lose water.
3. Slide 23 lists the highlights and 24 is a conclusion to the unit.

Focus questions – the Tasteful Garden

1. What is the main way Tasteful Garden markets their plants?

2. How did the Martin's get started with business?

3. What are the advantages of using internet marketing?

4. What are some of the limitations on using internet marketing of agricultural products?

5. What different skills and equipment would be needed to sell over the internet?

EFFECT OF LIGHT ON GERMINATION

Purpose: to demonstrate the importance of light in the germination of some seed.

This experiment is best done in the lab or classroom. Materials needed are lettuce seed, 2 pie pans, paper towels, one clear plastic bag, one heavy duty black plastic bag and two twist ties per team.

1. Place 10 lettuce seed on a wet paper towel in a pie pan. Place in the clear plastic bag and seal with a twist tie.
2. Place 10 more lettuce seed on a wet paper towel in a pie pan. Place in the black plastic bag and seal with a twist tie.
3. Place the pans in a warm, lighted location for 3-4 days. Take off the plastic bags and count the number of seed in each pan that have germinated. Record in the data table. Calculate the percentage of seed that have germinated by dividing the number of germinated seed by the beginning number of seed and multiplying by 100. For example, 4 divided by 10 = .4 times 100 = 40%.

Data Table

Treatment	Beginning # seed	# seed germinated	% of seed germinated
Clear plastic bag			
Black plastic bag			

Questions:

1. Which treatment had the highest percentage of germinated seed?

2. What factor necessary for germination was present in the treatment with the highest percent germination?

3. Do all seeds need light for germination? How do you know?

4. Design an experiment to test your hypothesis with bean seed.

EFFECT OF MOISTURE ON GERMINATION

Purpose: to determine the optimum level of moisture for germination.

This lab is best done in the classroom or lab. Materials needed are 30 bean or pea seed, one jar, two pie pans, two plastic bags, and paper towels per team.

Procedure:

1 Place 10 seed in a jar and fill completely with water.
2 Place 10 seed in a dry pie pan and place in a plastic bag.
3 Place 10 seed in a pie pan with a wet paper towel in the bottom. Place in a plastic bag.
4 In 3-4 days check and count the number of germinated seed in each trial. Record in the data table. Calculate the % germination by dividing the number of germinated seed by the beginning number of seed and multiplying by 100. For example, 5 divided by 10 = .5 times 100 = 50%.
5 Discard the germinated seed.
6 Drain the water from the jar and place the seed from the jar in the pie pan with the wet paper towel. Replace in the plastic bag.
7 Pour out the seed in the dry pan and place a wet paper towel in the pan. Replace the seed on the wet paper towel and place the pan in the plastic bag.
8 Check in 3-4 days and count the number of germinated seed and record in data table.

Treatment	Beginning # of seed	# of seed germinated after 3-4 days	% of seed germinated	# of seed for **second trial**	# of seed germinated after 3-4 days-**second trial**	% of seed germinated **Second trial**
Jar						
Dry pan						
Wet pan						

Questions:

1. Which treatment resulted in the highest percentage of seed germinated after the first trial? The least?

2. What factor necessary for germination was absent in the jar of water?

   The dry pan?

3. Which pan in the second trial had the highest percentage of seed germinated?
   Why do you think these seed germinated better than the others?

4. List the essential factors necessary for seed germination.

EFFECT OF TEMPERATURE ON GERMINATION

Purpose: to determine the best temperature for germination of bean seed.

This experiment can be carried out in the classroom. Materials needed are bean seed, 2 pie pans, paper towels, 2 plastic bags and twist ties per team.

Procedure:

1. Place 10 bean seed on a wet paper towel in a pie pan. Place in a plastic bag and put the bag in a warm place, at least 70 degrees. Measure the temperature and record.
2. Repeat the procedure, but this time place the pie pan in a cool place, at least 50 degrees. Measure the temperature and record.
3. Check the seed after 3-4 days and count the number that have germinated. Calculate the percentage of seed that have germinated by dividing the number of germinated seed by the beginning number of seed and multiplying by 100. For example, 4 divided by 10 = .4 times 100 = 40%.

Data table

Treatment	Beginning # seed	# seed germinated	Percentage of seed germinated
Warm, _____ degrees			
Cool, _____ degrees			

Questions:

1. Which treatment had the highest percentage of seeds that germinated?

2. Why do you think temperature affects germination?

3. Do you think that all seed have the same temperature requirements for germination? What evidence would you cite to support your answer?

MAKING A SOIL MIX

Purpose: to determine the best mix of ingredients needed to start vegetable seed.

This activity is best done outdoors. Have available various components of an organic soil mix such as peat, washed sand, compost, perlite, vermiculite, greensand, rock phosphate, cottonseed meal or alfalfa meal. Buckets, quart and pint containers, tablespoons, plastic wrap, seed, and flats will be needed for each team. All teams should plant the same type of seed. An alternative is to use a soil blocker and allow students to prepare soil blocks from their mix and plant their seed in the blocks.

Procedures:

1. Determine the proportions of your mix. Be sure to consider components to retain water and those needed to make the soil drain. Also determine the amount of nutrient containing substances you will add. Record in the data table in the form of 1 quart___to 2 quarts____, etc.
2. Mix up the soil in your bucket according to your recipe. Use the quart and pint containers to measure out the correct proportions. Make at least a gallon of soil.
3. Wet the soil and place in two flats. Plant 10 of the same kind of seed in each flat and cover each with a layer of plastic wrap.
4. Place flats in a warm place.
5. Check each day and count the number of seed that have germinated. Record in the data table. The length of the experiment will depend on the type of seed and how long they take to germinate.
6. At the end of the experiment, place the results of each team of students on the board and compare.

Soil mix recipe

Data table- Number of seed germinated

Trail	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
Flat 1										
Flat 2										

Questions:

1. Which soil mix had the highest percentage of germinated seed?

2. What other observations did you make about the flats?

3. What is the purpose of the plastic wrap?

UNIT 5 – CROP MANAGEMENT

I. INTRODUCTION

II. INSECT CONTROL

1. Attracting predators
2. Repellents
3. Barriers
4. Trap Crops
5. Killing

III. DISEASE CONTROL

IV. WEED CONTROL

V. COMPANION PLANTING

VI. UNIT SUMMARY

INTRODUCTION

The key to crop management in any farming system is the prevention of anything that will decrease the amount of crop harvested. Pest insects feeding on plants, for example, can reduce harvests or destroy crops. The key to prevention is healthy plants and the key to healthy plants is in the soil. Research has shown that healthy plants are not attacked as often by pest insects as less healthy plants.

Healthy plants are dependent on a diverse soil ecosystem and good nutrition from the soil biology. This makes them less susceptible to pest and disease attacks. But no matter how good the soil biology is at providing nutrition to plants, all systems experience some pest and disease problems. Weeds that compete with crops for nutrients and water are a constant problem everywhere.

The first step in any pest control system is monitoring. Observations need to be made on a daily basis to monitor pest types and numbers to determine when to intervene. This is important because any type of intervention costs time and money.

Another important tool in pest and disease control is identification and understanding the life cycles. Identification can be done using field manuals or by collecting a specimen or diseased tissue and sending it to the state extension office. (Contact your local extension agent about how to do this.) Once the pest is identified, a study of its life cycle will reveal when it is the most vulnerable to existing controls.

INSECT CONTROL

Objectives:

1. *Describe the five organic methods of insect control.*
2. *State the primary method of insect control.*
3. *State the last resort in organic insect control.*

Insect control in an organic farming system starts with good soil biology management, as mentioned above. However, even with good soil management, insect pests may be present in enough numbers to adversely affect crops and require some form of control.

The organic methods of insect control include:

- Attracting predators
- Repellents

- Barriers
- Trap Crops
- Killing

ATTRACTING PREDATORS

The first method, attracting predators, is the easiest and most cost effective. Predators will control pest insects, keeping the population below levels that are damaging to crops. All that is needed to attract them is adequate food and water.

Predator insects provide most of the protection for crops. They will be attracted to areas where there is an abundance of the insects they prey on or nectar-bearing flowers. Most predator insects will eat nectar and switch to pests when these are present. A list of high nectar plants suitable to your area can be obtained from extension offices. These are usually listed for honeybees, but predators feed on them also. It is important to have nectar-bearing flowers blooming throughout the growing season to retain the predator population. These insects will leave an area where food is not available, and lay eggs where food is adequate.

Predators will also need a source for water. The smaller ones will get most of their water from nectar and eating pests, but the larger ones may need another source. Ponds and small pools like birdbaths can provide this.

To maintain a large predator population on the farm, they will need habitat for refuge, breeding and egg-laying. Refuges for predators are undisturbed areas with plants. These can be as simple as unmown areas under fences or between fields. They can also be planted areas within fields such as strips of rye and vetch between strips of crops. Having a large diversity of plants allows for a wide diversity of predators.

REPELLENTS

A way to prevent pest insect damage is to repel them with a substance that can be sprayed on the plants. This is usually done with garlic oil that is commercially available in large quantities. It has a small quantity of soap that doesn't harm plants mixed in to make it soluble in water. This mix of garlic oil and soap is diluted in water and applied directly to the plants.

Another substance used to repel pests is an herb commonly called tansy. Cuttings from the plant can be boiled in water to make a tea. This can be diluted and applied.

These and other mixtures have the effect of making the plants unpalatable to the pests, resulting in little or no damage to the crops. These

repellants should be reapplied on a regular basis or after a rain. Application should be stopped enough ahead of harvest for the repellents to be washed off.

BARRIERS

Barriers are used to keep pest insects from being able to reach the crops. The most common and inexpensive type of barrier is floating row cover. This is a non-woven, synthetic cloth that is lightweight enough to be placed directly on plants without any support structure. It comes in various widths and can be used on beds or rows.

Floating row cover can be left on the beds or rows since 100 percent of the water that lands on it will pass through to the soil and 80 to 90 percent of the sunlight will be transmitted. An added benefit to growing under row covers is that it will act somewhat as an insulator, slightly raising the soil temperature underneath. This will result in more soil life activity in the spring and faster plant growth. A drawback is that must be removed when cultivating for weeds and replaced. It also will degrade in sunlight, lasting for only one or two crops before it becomes brittle and tears.

These covers are excellent for crops that are harvested before they bloom, like cabbage and broccoli, because they don't have to be removed to allow pollinators in. They can be left under row cover until harvest. This will prevent pests like cabbage moths from laying eggs on the plants. For those crops that require pollination, like squash, the row covers should be removed as soon as the first flowers bloom.

Another type of a barrier is a collar that is placed around new transplants. These are usually made of heavy paper or cardstock and protect tender plants from attack by cutworms. The collars are wrapped around the top of the root ball before they are transplanted so that there is about half inch of soil holding them in place. These are effective against both types of cutworms- those that chew through the stem at the soil level and those that climb the plant and eat the tops. Collars are used on transplants of tomatoes, tobacco and other crops attacked by cutworms.

TRAP CROPS

Trap crops are used to protect the main crop from a pest or a variety of pests. The trap crop can be a different plant species, variety, or just a different growth stage of the same species as the main crop, as long as it is more attractive to the pests when they are present. If given a choice,

cucurbit pests such as squash bugs and striped and spotted cucumber beetles prefer squash and pumpkins to watermelons, cantaloupes, cucumbers, and gourds—in that order.

Trap cropping tends to work best for insects of intermediate mobility rather than those, like aphids, that are passively dispersed by air currents, or insects that are strong fliers.

Trap crops are more economical to use if the system is easily planted and maintained, if they have some other use, such as supporting beneficial insects or if they can also be marketed. If they require a small amount of space relative to the main crop, they will be more economical.

The required trap crop planting size depends upon the intensity and direction of the pest attack expected, as well as the mobility of the target pest insect. Usually, planting a trap crop around the perimeter of a crop area will be effective against insects of intermediate mobility.

The type of plants to use as trap crops varies according to the intended crop and expected types of pest insects. These will also vary due to the differences in climate within the state. One plant that is commonly used as a perimeter trap is collard greens to protect cabbage. All extension offices can help with planning trap crops.

KILLING

When pest insect populations reach the critical point where crop damage is unacceptable, some type of intervention is needed. The most time and cost effective intervention at this point is to kill off the pest population. This can be done using insecticides that target only the pests. If there is no target insecticide available, a broad-spectrum insecticide that is acceptable under the organic rule can be used. In small-scale operations or small numbers of specialty crops, techniques like hand picking are effective.

An insecticide that targets the pest insects and does not kill the beneficials can be effectively used. However, some understanding of the life cycles of the pests and the insecticides used is necessary. One product that targets soft-bodied insects is insecticidal soap. This is effective in controlling aphids by dissolving the waxy coating on the outside of their bodies and causing them to dehydrate. Because of the way it works, the pests must be drenched in the soap solution. This requires direct contact with the solution so that it covers the pests.

Another insecticide that targets specific pests is ultra-refined vegetable oil. This is prepared so it is soluble in water and can be diluted. A solution of this oil can be sprayed on larval forms of insects to kill them.

When the solution dries, the oil turns into a paraffin-like coating that smothers the larvae. Again, the pests must be drenched with the solution for it to be effective, unlike the broad-spectrum insecticides.

Another insecticide that is effective on the larval form of insects is *Bacillus thuringiensis* or Bt. This is a soil bacterium that contains a chemical toxic to larval insects. The Bt that is available contains weakened or dead bacteria. The Bt powder is dusted onto plant surfaces being eaten by larva, the bacteria are ingested and the toxin is released. Bt acts by blocking the larvae from absorbing nutrients in their digestive systems.

All of these insecticides take some time to kill the pests- from hours for soap and oil, to days for the Bt. But they do not need to be reapplied unless rain or overhead irrigation washes the insecticide off the pests' bodies or the plant surfaces being eaten.

The broad-spectrum insecticides (sometimes called botanicals) allowed by organic standards are all derived from plant material. These include rotenone, pyrethrum, sabadilla and others. They are called broad-spectrum because they kill almost all of the insects that come in contact with them- pests and beneficials. These are the only substances known to be effective on the adult stage of most insects.

Since they kill most of the insects they should be used only as a last resort and to save a crop that would otherwise be destroyed. There are two cautions about using these insecticides. The first is the misconception that, since these are organic, they are safe. Most of these insecticides are nerve agents and affect people as well. They should be handled and applied in the same way as chemical pesticides: Wear protective clothing and a respirator, avoid skin contact or inhalation of the powders, and wash immediately if contact happens. The safest way to apply these is as a solution, so wettable forms should be purchased.

Another caution is in making sure that a botanical insecticide does not contain any chemical insecticides that may void your organic certification. Some companies add these to insure their effectiveness. Be sure to contact your certifying agent before purchasing any such product to ensure that it is approved for use.

Botanicals have a much shorter shelf life than chemically produced insecticides. They should be stored carefully to maintain potency, avoiding moisture, and they should be used in the year they are purchased. In addition, they are considered toxic waste and should be disposed of through a toxic-waste collection program.

SUMMARY

Even with good soil management insects sometimes have to be controlled in other ways. Preventive methods of inset control include planting or leaving an area for predator insects to live and planting trap crops for the harmful insects. Barriers can be used to prevent insects from getting to the crop and repellants keep them away. Organic insecticides can be used to treat an infestation of insects, though they kill all insects, both beneficial and harmful. Identification and knowledge of the life cycle allow the botanicals to be used most effectively.

DISEASE CONTROL

Objectives:

1. *List the three causes of disease in plants.*
2. *Identify the control method for bacterial or viral diseases.*
3. *Describe the three steps in disease control.*
4. *Name the most common cause of plant disease.*

Again, the key to disease control is prevention. And this is done by providing the plants with good nutrition through soil management. Diseases will attack weak plants or plants growing in soils which lack the biodiversity to suppress diseases. There are a few common viral and bacterial diseases, like tobacco mosaic virus (spread by contact) and bacterial wilt (spread by cucumber beetles), but most are fungal.

Bacterial wilt

Tobacco mosaic virus

Like insect pests, disease control starts with identification. Tissue samples or photos of the diseased plants can be sent to the extension office where a specialist can diagnose the disease. Once this is known, organic disease controls can be administered.

In the case of a bacterial or viral disease, there is nothing that will slow down or stop the disease. In these cases, prevention is the only form of control. With the example of tobacco mosaic virus, this means preventing contact with anything that may carry the virus. The most common vector is tobacco products. These should be kept away from plants and growing areas. In addition, anyone using tobacco products should wash their hands thoroughly before working with plants.

The most common vector for bacterial wilt is the striped and spotted cucumber beetle. The bacteria that cause this disease cannot survive in dry plant material for more than a few weeks so affected plants are not a problem. The bacteria live through the winter in the gut of the adult beetles and plants are infected when these feed on the plants. Preventing beetles from feeding on crops is the only known prevention.

Fungal disease is the most common and, fortunately, the most treatable. There are many different fungal diseases and they attack plants in different ways. The most obvious one is commonly called powdery mildew. This appears as a white to gray-looking powder on the leaves of plants. Powdery mildew can grow on a large variety of plants, from squash to trees, and can over-winter on these and other weeds.

Powdery mildew

A few years ago, researchers discovered a new alternative for controlling powdery mildew. A scientist from Brazil found that weekly sprays of milk controlled powdery mildew in zucchini just as effectively as synthetic fungicides. Not only was milk found to be effective in controlling the disease, it also acted as a foliar fertilizer, boosting the plant's immune system. The most effective mixture is a 10% solution of milk in water. Research work in New Zealand found that using skim milk was just as

effective as whole milk. It was cheaper and since the milk had no fat content, there was less chance of any odors.

Some fungi that attack plants live in the soil and grow into the roots of weak plants. An example of this is *fusarium*. *Fusarium* will flourish in a soil where the biodiversity has been lessened through poor management or fumigation. *Fusarium* is controlled through biodiversity in the soil. An important part of control is reduction of tillage to promote the growth of beneficial fungi that control this and other disease-causing fungi.

The process of disease control includes:

- Identification of the disease.
- Looking at its life cycle to determine when it is most vulnerable.
- Determining the best course of action.

We can look at apple scab as an example of how to think about disease control. Apple scab is caused by a fungus (*Venturia inaequalis*). It grows on leaf surfaces during spring and summer. The spores for new fungal growth over-winter on the surface of fallen leaves. In the spring, when the temperature and humidity are at the right levels, the spore cases open and fungal spores are released. These spores infect the leaves and cause "scab" lesions to form. In the fall, the dead leaves fall and the cycle starts over.

The easiest way to prevent the re-infection of the trees is to look at the life cycle of the fungus to determine at what stage it is the most vulnerable to intervention. The life cycle of apple scab, by season, is:

- Spring-spore cases open and spores are released.
- Summer-fungus grows on leaves and produces spore cases.
- Fall-leaves containing spore cases drop on ground.
- Winter-leaves lie on ground and those which do not decompose, release spores in spring.

The first part of the life cycle, spore release in the spring, is impossible to prevent. The spore cases are tiny and individual spores cannot be seen. So, there is no way to tell when this happens. In addition, the spores in individual cases are released at different times and different days.

In the summer, when the fungus is growing on the leaves, it is expensive in time and money to try to control it. Spraying would have to be done on a regular basis and there are few fungicides that are approved for organic use.

In the fall and early winter when the leaves have fallen is the easiest time to control the fungus. The leaves can be gathered and composted or burned. (If composting, be sure that the leaves are completely decomposed in a hot pile.)

SUMMARY

Diseases in plants are caused by bacteria, viruses, and fungi, with fungi causing the most disease. Prevention is the only way to treat diseases of bacteria and viruses, but there are some control methods for fungal diseases. Identification, knowledge of the life cycle and determining the best course of action are necessary for disease control.

WEED CONTROL

Objectives:

1. *Identify the time in the weed life cycle that it is easiest to control.*
2. *Describe four ways to control weeds within the organic standards.*

Weed control in an organic system is mostly limited to mechanical means. This can be done using implements such as cultivating tines or harrows with a tractor. Alternatively, a hoe can be used for handwork.

The main thing with mechanical weed control is to kill the weeds when they are young and small, before they have a chance to get established or compete with crops. Killing the weeds while they are young also prevents them from making more seed. Setting the cultivating equipment deep enough to disturb the roots of the young weeds will kill them. However, care should be taken not to go too deep and disrupt the beneficial soil life, like the mycorrhizal fungi.

If weeds have been allowed to get larger, they can still be killed with mechanical cultivation. Tines can be set deep enough to cut the growing crown of the weeds from the roots, leaving the roots undisturbed. This will kill most common weeds.

On a smaller scale, there are hand tools that are helpful in making weeding more efficient. A wheel hoe can greatly speed up the weeding process, especially when the weeds are small. Stirrup hoes which cut off the weed at the ground level are very effective. Weeding on a hot, dry day will ensure that the weeds pulled up will die. If weeds are left in the field, and it rains, some will re-root. Sharp edged diamond hoes are effective at reaching weeds growing between plants The key to all effective methods of weed

control is to destroy the weeds early before they develop extensive root systems.

Flame weeding is another method used to control weeds. The idea behind flame weeding is to kill weeds with a wave of heat, without disturbing the soil or harming the crop root system. A thin line of heat directed at the stalk will boil the water within the weed's cells. The pressure generated by this expanding water will rupture the cells, destroying a cross section of the stalk. When this happens, plant food and water cannot move from roots to leaves and the plant withers and dies. The point of flaming is not to charbroil the weeds, but heat them just enough so that they wilt.

The most effective method is to catch weeds early, from 1-4 inches. At this small stage, flaming is nearly 100 percent effective, whereas weeds over 4 inches are more difficult to kill without an extended dose of heat. By destroying cell structure in the plant leaf, the weed will no longer put energy toward growth. So even on big weeds, there will be a stunting effect or even a kill, depending on how established the root system is and how long the plant was exposed to heat.

Flaming can be done with a small propane torch in small areas. However, for larger areas one of the weed flaming torches is an excellent tool. Flame weeders with multiple torches, or heads, are available to cover large areas.

Another technique for controlling weeds is use of a material to cover the ground and block out the sunlight. One of the most common materials used is black plastic. Other colored plastics, woven weed block material and various papers may also be used. The organic standards require that plastic materials be removed from the fields at the end of each season.

One other method of controlling weeds is to use a stale bed. To create a stale bed an area is tilled and allowed to sit undisturbed until the weeds have germinated. It is then lightly cultivated to kill the weeds with as little disturbance of the soil as possible. Depending on the weed seed load in the soil, the plot can be either planted immediately or allowed to go through another cycle of germination and cultivation before planting.

There are some agents that are approved as organic herbicides. These include corn gluten and vinegar. Corn gluten used as a pre-emergent is effective only on turf weeds like crabgrass, and is most effective in the spring when they are germinating. Another is vinegar. This is used in a solution and is most effective as a spot killer. Vinegar has been used in widespread applications as an exfoliant before picking organic cotton. However, vinegar will kill some of the soil life and have an effect on soil pH. It will also temporarily sterilize the soil if used in a high concentration.

SUMMARY

The most effective method of weed control in organic systems is mechanical cultivation, either with a hand-held hoe or a tractor cultivator. Flame weeding, plastic mulches, and organic herbicides can provide control in certain circumstances.

COMPANION PLANTING

Objectives:

1. *Define companion planting.*
2. *State three reasons to use companion plants.*
3. *Describe two factors to consider when deciding on companion plants.*

Companion planting is the method of growing two or more crops in the same row or bed. This area has not been the subject of very much scientific research. Most of our knowledge about companion planting comes from trial and error over many years and from different parts of the world. Lists of crops that can be grown together can be found in a number of sources. Some of these lists also contain information about antagonists, or crops which do poorly when planted together.

COMPANION PLANTING CHART FOR HOME & MARKET GARDENING (compiled from traditional literature on companion planting)		
CROP	**COMPANIONS**	**INCOMPATIBLE**
Asparagus	Tomato, Parsley, Basil	
Beans	Most Vegetables & Herbs	
Beans, Bush	Irish Potato, Cucumber, Corn, Strawberry, Celery, Summer Savory	Onion
Beans, Pole	Corn, Summer Savory, Radish	Onion, Beets, Kohlrabi, Sunflower
Cabbage Family	Aromatic Herbs, Celery, Beets, Onion Family, Chamomile, Spinach, Chard	Dill, Strawberries, Pole Beans, Tomato
Carrots	English Pea, Lettuce, Rosemary, Onion Family, Sage, Tomato	Dill
Celery	Onion & Cabbage Families, Tomato, Bush Beans, Nasturtium	
Corn	Irish Potato, Beans, English Pea, Pumpkin, Cucumber, Squash	Tomato
Cucumber	Beans, Corn, English Pea, Sunflowers, Radish	Irish Potato, Aromatic Herbs
Eggplant	Beans, Marigold	
Lettuce	Carrot, Radish, Strawberry, Cucumber	
Onion Family	Beets, Carrot, Lettuce, Cabbage Family, Summer Savory	Beans, English Peas
Parsley	Tomato, Asparagus	
Pea, English	Carrots, Radish, Turnip, Cucumber, Corn, Beans	Onion Family, Gladiolus, Irish Potato
Potato, Irish	Beans, Corn, Cabbage Family, Marigolds, Horseradish	Pumpkin, Squash, Tomato, Cucumber, Sunflower
Pumpkins	Corn, Marigold	Irish Potato
Radish	English Pea, Nasturtium, Lettuce, Cucumber	Hyssop
Spinach	Strawberry, Fava Bean	
Squash	Nasturtium, Corn, Marigold	Irish Potato
Tomato	Onion Family, Nasturtium, Marigold, Asparagus, Carrot, Parsley, Cucumber	Irish Potato, Fennel, Cabbage Family
Turnip	English Pea	Irish Potato

Adapted from Kuepper, George, and MardiDodson, 2001. Companion Planting: Basic Concept and Resources. ATTRA, Fayetteville, AR.

Companion planting is usually done in backyard gardens where space is a consideration. It is sometimes called *inter-cropping* when used on farms. However, it can be used in farm operations for a number of reasons.

The first of these reasons is to increase the amount of food produced per area of land. Two or more compatible crops can be grown in the same bed or row as long as this does not interfere with cultivation or harvest. An example of this is planting pole beans between corn plants when the corn is about a foot high. The beans do not compete with the deep-rooted corn for nutrients and water and the corn provides a trellis. This works where the corn is hand-harvested, leaving the stalks to support the bean vines.

This can also be done using a crop that matures rapidly and is harvested before the other competes for nutrients and water or the larger one shades the smaller. An example of this is planting radish seeds between young lettuce or spinach transplants in the spring when soil temperatures are right for germination. The radishes will develop rapidly and can be harvested before the lettuce shades them.

Another reason for companion planting is to reduce or eliminate the chance of a soil-borne disease. Very few scientific studies have been done on this. One of these types of relationships was discovered by accident in Japan. (See Unit 1) Since alliums protect plants susceptible to *fusarium* attack, they can be planted with these susceptible plants. One example would be to interplant onions with tomatoes or melons.

A third reason for companion planting would be to repel pests from certain crops. This is usually done by planting or placing plants that contain aromatic oils next to the crop to be protected. Care needs to be taken not to plant something that would be antagonistic to the crop. An example of this is the use of geraniums to repel cabbage moths.

One of the main considerations in choosing companion crops, along with antagonism, is the potential for competition. Root depth and/or type should be different, as in the example given of lettuce and radishes. Lettuce has an extensive and spreading root system, and radishes have taproots that go straight down and don't spread much. In the example of beans and corn, legumes have a shallow root system and corn a deep one.

SUMMARY

Growing different plants together is called companion planting. It can be done to increase food production from a given area of land. This practice seems to protect the plants from some soil-borne diseases and pests.

Antagonism and competition between the plants must be considered when deciding on companion planting. Little scientific research has been carried out in this area.

UNIT SUMMARY

Good soil management that results in healthy plants is the first and most important line of defense against insect and disease problems. Insects can also be controlled with predatory insects, barriers, trap crops, repellents, and organic insecticides. Diseases caused by bacteria, viruses and fungi are controlled by good soil management and managing the crop to minimize conditions which favor disease. Weeds are a problem for all organic farms. Mechanical cultivation is the most effective method of control but flame weeding, plastic mulches, and the use of organic herbicides can be effective in certain circumstances.

Companion planting allows for increased crop production and some resistance to soil-borne diseases and pests. Care must be taken to consider antagonist reactions between plants and competition for water and nutrients when deciding on the plants to be companions.

LESSON PLANS WITH OBJECTIVES – CROP MANAGEMENT

I AND II. INSECT CONTROL

OBJECTIVES:

4. Describe the five organic methods of insect control
5. State the primary method of insect control
6. State the last resort in organic insect control

LESSON PLAN:

1. Start the class with a discussion of the common belief that the only way to control insects is with chemical pesticides. Have some **containers of chemical insecticides** and read the cautions to the class. Use Unit 5 power point slides1-9 to talk about the various methods of organic control.
2. Explain how healthy plants can withstand some insect damage and the importance of soil health for plant health.
3. For each of the 5 organic methods of control, explain the mechanism and give an example. When possible, show the class an example of each type. For example, **a piece of row cover, a container of Bt powder, and garlic spray** would be visuals the students could identify.
4. Identify the need to scout crops and identify the insects present. Use the power point presentation slides 11-77 to talk about when insects are most vulnerable to control and help students identify common insect pests and beneficial insects. The powerpoint **Life Cycle of Insects** may be used to illustrate the best times for control.
5. If possible, visit a greenhouse and find and identify insects found in the greenhouse. The demo plot should also be **scouted for insects** and those found brought in for identification and a discussion on the best control plan, if damage is severe.

III. DISEASE CONTROL

OBJECTIVES:

5. List the three causes of disease in plants.
6. Identify the control method for bacterial or viral diseases.
7. Describe the three steps in disease control.
8. Name the most common cause of plant disease.

LESSON PLAN:

1. Ask students what causes disease in humans. Relate their answers to the three cause of disease in plants – bacteria, viruses, and fungi.
2. Uses Unit 5 power point slides 78-83 to explain and illustrate plant diseases.
3. Explain that the only way to deal with bacteria or viruses in plants is to try to prevent the infection. This is true across the board, not only in organic systems. The most common cause of disease, fungi, has a few organic treatments. The web site http://www.apsnet.org/ has an image of the week that you can download and use in your classes.
4. Relate the three steps of disease control to the methods of controlling insects: Identification, life cycle determination, best method of control.

IV. WEED CONTROL

OBJECTIVES:

3. Identify the time in the weed life cycle that it is easiest to control.
3. Describe four ways to control weeds within the organic standards.

LESSON PLAN:

1. Take students to an outside area and point out some of the weeds. Ask the students what they all have in common. There common feature is that they are growing where we don't want them to grow – this is what makes them weeds.
2. Use Unit 5 power point presentation slides 84-133 to talk about weed control and to help students identify specific weeds.
3. Visit the demonstration plot and identify and **Pull the weeds**.

V. COMPANION PLANTING

OBJECTIVES:

4. Define "companion planting".
5. State three reasons to use companion plants.
6. Describe two factors to consider when deciding on companion plants.

LESSON PLAN:

1. Use an analogy of how some people get along well and others don't to establish the idea of companion planting.

2. Use Unit 5 power point presentation slides 134-135 to explain companion planting and the benefits and disadvantages of companion planting.
3. Use the **Table of companion plants** to show students the types of plants that are good companions and those that don't work well together.
4. Remind students that plants can be grouped in families, and ask students to look for patterns in the recommendations for companions, and description of antagonist.
5. Describe crop rotation as a method of control using Unit 5 power point presentation slide 136-137.
6. Use the **Crop Rotation Worksheet, Rotation Guidelines, and Yield and Value Worksheet** to have students practice designing a rotation and estimating the value of crops they may grow.
7. Conclusion of the unit on slide 137.

Locally Grown Crop Video – Focus Questions

1. Who makes up the Locally Grown Coop and where are they located?
2. How does the coop communicate with their customers?
3. What is the advantage of this type of marketing for the farmer?
4. What is the advantage for the consumer?
5. What feature makes the Locally Grown Coop unique?

SCOUTING FOR INSECTS

Purpose: to learn to identify insects and practice developing a plan of action to control insect damage.

This activity should be done regularly once the demonstration plot is planted.

1. Students should inspect the plants closely for insect damage or insect presence.
2. If insects are found, one or more should be collected and brought to the classroom. Damage caused by the insect should be determined.
3. Using the power point presentation, **Insect life cycles,** or an insect ID book, identify the insect and determine the life stage.
4. Determine if control is necessary. If damage is significant, plan the best method of control.
5. Students should carry out the control as needed.

Questions:

1. List the insects found in the demonstration plot.

2. Which of these insects are harmful?

3. How do they harm the plant?

4. What did the damage to the plant look like?

5. What stage of the life cycle were the insects in?

6. If damage was severe enough to warrant control, what factors did you use to decide on the method of control?

7. Was the method of control you used effective?

PULLING WEEDS

Purpose: to learn to identify weeds and practice methods of control

This activity should be carried out regularly once the plants are established in the demonstration plot.

1. Check out the students' ability to identify the crop plants that have been planted.
2. Each student should be assigned a section of the plot to weed. Weed by hand, at least once, pulling up the weeds by the roots when possible.
3. Sort the weeds into groups of like plants.
4. Bring a representative of each group into the classroom and identify, using the power point presentation **Weed ID** or a weed identification book.
5. Discuss ways to decrease the number of weeds in the demonstration plot.

Questions:

1. What seemed to determine how easy the weeds were to pull?

2. Was there a variety of weeds or many of the same kind present?

3. Why do you want to remove weeds from around the crops?

4. How is weed control different in organic systems than in chemical based systems?

5. What methods of organic weed control can you name?

Plants for prolonged-blooming bee pasture in the Southeast					
Common Name	**Scientific Name**	**Type**	**Availability**	**Resource (nectar or pollen)**	**Bloom Dates**
Cajeput (Tea Tree)	*Melaleuca quinquenervia*	tree	feral	n,p	much of the year
Chickweed	*Stellaria* spp.	ann. or per. herb	feral	n,p	much of the year
Cucumber	*Cucumis sativa*	ann. herb	cultivated	n,p	much of the year
Pumpkin	*Cucurbita* spp.	ann.	cultivated	n,p	much of the year
Alder	*Alnus* spp.	tree	feral	p	January-June
Blueberry	*Vaccinium* spp.	shrub	cultivated, feral	n,p	January-June
Maple	*Acer* spp.	tree	feral	n,p	January-May
Cantaloupe	*Cucumis melo*	ann. herb	cultivated	n,p	February-August
Citrus	*Citrus* spp.	tree	cultivated	n,p	February-May
Dandelion	*Taraxacum* spp.	bien. or per. herb	feral	n,p	February-September
Dead Nettle (Henbit)	*Lamium* spp.	ann. or per. herb	feral, ornamental, sometimes invasive	p	February-October
Elm	*Ulmus* spp.	tree	feral	n,p	February-April
Groundsel	*Senecio* spp.	ann. or per. herb, shrub	feral, ornamental	n,p	February-May
Hawthorn	*Crataegus* spp.	shrub, tree	feral	n,p	February-June
Peach	*Prunus persica*	tree	cultivated	n,p	February-April
Pine	*Pinus* spp.	tree	cultivated, feral	p	February-April
Skunk Cabbage (Polecat Weed)	*Symplocarpus foetidus*	per. herb	feral, ornamental	p	February-April
Titi (Spring Titi)	*Cliftonia* spp.	shrub	feral	n,p	February-April
Willow	*Salix* spp.	tree	feral	n,p	February-June
Apple	*Malus* spp.	tree	cultivated	n,p	March-May
Ash	*Fraxinus* spp.	tree	feral	p	March-May
Blackberry	*Rubus* spp.	shrub	cultivated, feral	n,p	March-June
Black Locust	*Robinia pseudoacacia*	tree	feral	n,p	March-June
Cherry (cultivated and uncultivated)	*Prunus* spp.	tree, shrub	cultivated, feral	n,p	March-May
Cottonwood	*Populus* spp.	tree	feral	p	March-May
Flowering Dogwood	*Cornus florida*	tree	feral	n,p	March-April
Gallberry	*Ilex glabra*	shrub	feral	n,p	March-June
Mustard	*Brassica* spp.	ann. or bien. herb	feral	n,p	March-September
Oak	*Quercus* spp.	tree	feral	p	March-May
Persimmon	*Diospyros virginiana*	tree	cultivated, feral	n,p	March-June
Plum (cultivated)	*Prunus* spp.	tree	cultivated	n,p	March-April
Rape (Canola)	*Brassica napus*	ann. herb.	cultivated oilseed	n,p	March-May
Rattan Vine	*Berchemia scandens*	shrub	feral	.	March-June
Redbud	*Cercis* spp.	shrub, tree	feral, ornamental	n,p	March-May

Tupelo	*Nyssa* spp.	tree	feral	n,p	March-June
Vervain	*Verbena* spp.	ann. or per. herb	feral, ornamental	n,p	March-October
Alsike Clover	*Trifolium hybridum*	per. herb	cultivated forage	n,p	April-September
Bindweed	*Convolvulus* spp.	ann. or per. herb	feral, ornamental, sometimes invasive	n,p	April-September
Buckeye	*Aesculus* spp.	shrub, tree	feral	n,p	April-May
Buckthorn	*Rhamnus* spp.	shrub, tree	feral, ornamental	n,p	April-June
Catclaw	*Acacia greggii*	shrub, tree	feral	n,p	April-July
Coneflower	*Rudbeckia* spp.	ann., bien, or per. herb	feral, ornamental	n,p	April-September
Corn	*Zea maize*	ann.	cultivated	p	April-September
Crimson Clover	*Trifolium incarnatum*	ann. herb	cultivated forage	n,p	April-June
Elderberry	*Sambucus* spp.	shrub, tree	feral, ornamental	n,p	April-July
Holly	*Ilex* spp.	shrub, tree	feral, ornamental	n,p	April-June
Honey Locust	*Gleditsia triacanthos*	tree	feral	n,p	April-June
Honeysuckle	*Lonicera* spp.	shrub	feral	n,p	April-August
Horsemint (Bee Balm)	*Monarda* spp.	ann. or per. herb	feral, ornamental	n,p	April-October
Huckleberry	*Gaylussacia* spp.	shrub	feral	n,p	April-June
Johnson Grass	*Sorghum halepense*	per.	cultivated forage, feral, sometimes noxious	.	April-November
Marigold	*Gaillardia pulchella*	ann.	feral, ornamental	n,p	April-October
Mesquite	*Prosopsis glandulosa*	shrub, tree	feral	n,p	April-June
Pear	*Pyrus* spp.	tree	cultivated, ornamental	n,p	April-May
Pepper Vine	*Ampelopsis* spp.	vine, shrub	feral	n,p	April-August
Persian Clover	*Trifolium resupinatum*	ann. herb	.	n,p	April-September
Privet	*Ligustrum* spp.	shrub	feral, ornamental	n,p	April-July
Red Clover	*Trifolium pratense*	short-lived per.	cultivated forage	n,p	April-September
Sage	*Salvia* spp.	ann. or per. herb, shrub	ornamental	n,p	April-May
Sweet Clover (White, Yellow)	*Melilotus* spp.	bien. herb	cultivated forage	n,p	April-October
Thistles	*Cirsium* spp.	ann., bien., or per. herb	feral	n,p	April-October
Tickseed	*Coreopsis lanceolata*	per. herb	feral	n	April-June
Titi (Summer Titi)	*Cyrilla racemiflora*	shrub	feral	n,p	April-July
Tulip Poplar	*Liriodendron tulipifera*	tree	feral	n,p	April-June
Vetch	*Vicia* spp.	ann. or bien. herb	cultivated forage	n,p	April-September
White Clover (White Dutch, Ladino)	*Trifolium repens*	per.	cultivated forage	n,p	April-October

Yellow Rocket	*Barbarea vulgaris*	bien. or per. herb	feral, sometimes noxious	n,p	April-June
Alfalfa	*Medicago sativa*	per. herb	cultivated forage	n,p	May-October
American Beautyberry (French Mulberry)	*Callicarpa americana*	shrub	feral, ornamental	n	May-June
Aster	*Aster* spp.	per. herb	feral	n,p	May-November
Bermuda Grass	*Cynodon dactylon*	per. grass	cultivated forage	.	May-November
Bitterweed	*Helenium amarum*	ann.	feral	n,p	May-November
Carpet Grass	*Phyla nodiflora*	per. herb	feral, groundcover	n	May-frost
Catalpa (Catawba)	*Catalpa* spp.	tree	feral	n,p	May-June
Chinese Tallow Tree	*Sapium sebiferum*	tree	ornamental	n	May-June
Grape	*Vitis* spp.	per. vine	cultivated	n,p	May-July
Palmetto (Cabbage Palm)	*Sabal* spp.	palm	feral	n,p	May-July
Palmetto (Saw Palmetto)	*Serenoa repens*	palm	feral	n,p	May-July
Prickly Pear	*Opuntia* spp.	cacti, tree-like	feral, ornamental	n,p	May-June
Raspberry	*Rubus* spp.	shrub	feral	n,p	May-June
Smartweed	*Polygonum* spp.	ann. or per. herb	cultivated, feral, ornamental	n,p	May-November
Sorghum	*Sorghum bicolor*	ann.	cultivated	p	May-October
Sourwood	*Oxydendrum arboreum*	tree	feral, ornamental	n,p	May-July
Spanish Needles	*Bidens* spp.	ann. or per. herb	feral, ornamental	n,p	May-November
Sumac	*Rhus* spp.	shrub, tree	feral	n,p	May-September
Virginia Creeper	*Parthenocissus quinquefolia*	vine	feral, ornamental	n,p	May-August
Watermelon	*Citrullus lanatus*	ann.	cultivated	n,p	May-August
Anise Hyssop	*Agastache* spp.	per. herb	feral, ornamental	n,p	June-September
Balloon Vine	*Cardiospermum halicacabum*	ann. or bien. vine	feral, ornamental	.	June-August
Basswood	*Tilia* spp.	tree	feral	n,p	June-July
Blue Vine	*Cynanchum laeve*	per. herb	feral	n,p	June-September
Boneset (Joe-Pye Weed)	*Eupatorium* spp.	per. herb, shrub	feral, ornamental	n,p	June-November
Buckwheat	*Fagopyrum esculentum*	herb	cultivated	n,p	June-frost
Buttonbush	*Cephalanthus* spp.	shrub, tree	feral	n,p	June-September
Clethra (Sweet Pepperbush)	*Clethra alnifolia*	shrub	feral	n,p	June-September
Cotton	*Gossypium* spp.	ann. herb	cultivated	n,p	June-September
Cowpea	*Vigna unguiculata*	ann. herb	cultivated	n,p	June-September
Cranberry	*Vaccinium macrocarpon*	evergreen	cultivated, feral	n,p	June-July
Ironweed	*Vernonia* spp.	per. herb, shrub, tree	feral, ornamental	n,p	June-October
Lespedeza (Bush	*Lespedeza* spp.	per. herb, shrub	feral, ornamental	n,p	June-October

Clover)					
Lima Bean	*Phaseolus lunatus*	herb	cultivated	n,p	June-July
Loosestrife (Purple Loosestrife)	*Lythrum salicaria*	per. herb	cultivated, feral	n,p	June-September
Mexican Clover	*Richardia scabra*	ann. herb	cultivated, feral	n	June-frost
Milkweed	*Asclepias* spp.	per. herb	feral	n	June-August
Mint	*Mentha* spp.	per. herb	cultivated, feral, ornamental	n	June-September
Partridge Pea	*Cassia fasciculata*	ann. herb	feral	n,p	June-October
Prickly Ash	*Aralia spinosa*	shrub, tree	feral	n	June-August
Star Thistle	*Centaurea* spp.	ann., bien., or per. herb	feral, ornamental	n,p	June-October
Sunflower	*Helianthus* spp.	ann. or per. herb	cultivated ornamental and oilseed, feral	n,p	June-November
Vitex (Chaste Tree)	*Vitex* spp.	shrub, tree	ornamental	n,p	June-July
Broomweed	*Gutierrezia texana*	per. herb	feral	.	July-October
Goldenrod	*Solidago* spp.	per. herb	feral	n,p	July-November
Ragweed	*Ambrosia* spp.	herb	feral, often noxious	p	July-October
Snowvine	*Mikania scandens*	per. vine	feral	n,p	July-frost
Soybean	*Glycine max*	ann. herb	cultivated	n,p	July-October
Woodbine	*Clematis virginiana*	per. herb	feral, ornamental	n,p	July-September
Brazilian Pepper Tree	*Schinus terebinthifolius*	shrub, tree	feral, ornamental, sometimes noxious	.	August-October
Crown-beard	*Verbesina* spp.	ann. or per. herb, shrub, tree	feral	n,p	August-October
Matchweed (Snakeweed)	*Gutierrezia sarothrae*	per. herb	feral	n,p	August-October
Prairie clover	*Dalea* spp.	herb, shrub	feral	n,p	September-October
Baccharis (Groundsel)	*Baccharis* spp.	shrub	feral, ornamental	n,p	October-November
Strawberry	*Fragaria x ananassa*	per. herb	cultivated,feral	n,p	December-May

Table provided by the University of Georgia Extension Service *Bee Conservation in the Southeast* by Keith S. Delaplane

CROP ROTATION WORKSHEET

The purpose of this exercise is to give you some practice in planning crop rotations. As you go through the process you will identify ways to make the planning more efficient.

Identify 10-12 different crops you would like to grow. Write them below.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.

Use similarities in family (solanacea, legume…), crop type (root, leaf…), season (early, fall…), management type (trellis, plastic mulch…) or some other criteria to group your crops into 3-5 groups.

Each of the groups you made should be allotted the same amount of land. Your total amount of land is 1000 square feet.

Write the name of each group on an index card and arrange your field layout so one group will follow another in rotation, using the "Rotation Guidelines".

Sketch your rotation plan below, defining the number of feet of each crop in the group.

Trap Crops

Trap crop	Main crop	Method of planting	Pest controlled
Alfalfa (Meyer, 2003)	Cotton	Strip intercrop	Lygus bug
Basil and marigold (MMSU, 2003)	Garlic	Border crops	Thrips
Castor plant (Hasse, 1986; 1987)	Cotton	Border crop	*Heliotis sp.*
Chervil (Ellis; Bradley, 1996)	Vegetables Ornamentals	Among plants	Slugs
Chinese cabbage, mustard, and radish (Facknath, 1997; Muniappan; Lali, 1997)	Cabbage	Planted in every 15 rows of cabbage	Cabbage webworm Flea hopper Mustard aphid
Beans and other legumes	Corn	Row intercrop	Leafhopper Leaf beetles Stalk borer Fall armyworm
Chick pea (Grundy; Short, 2003)	Cotton	Block trap crop at 20 plants/ sq m (Brown, 2002)	*Heliotis sp.*
Collards (Boucher; Durgy, 2003)	Cabbage	Border crop	Diamondback moth
Corn (Hasse, 1986; 1987)	Cotton	Row intercrop, planted in every 20 rows of cotton or every 10-15 m	*Heliotis sp.*
Cowpea (CIKS, 2000)	Cotton	Row intercrop in every 5 rows of cotton	*Heliotis sp.*
Desmodium (ICIPE, 2003)	Corn Cowpea Millet Sorghum	Row intercrop	Stemborer Striga
Dill and lovage (Ellis; Bradley, 1996)	Tomato	Row intercrop	Tomato hornworm
Green beans (Ellis; Bradley, 1996)	Soybean	Row intercrop	Mexican bean beetle
Horse radish (DA, Philippines, 1997)	Potato	Intercrop	Colorado potato beetle
Hot cherry pepper (Boucher; Durgy, 2003)	Bell pepper	Border crop	Pepper maggot
Indian mustard (Cornell University, 1995)	Cabbage	Strip intercrop in between cabbage plots	Cabbage head caterpillar
Marigold (French and African marigold) (Vann; Kirkpatrick;	Solanaceous Crucifers Legumes	Row/strip intercrop	Nematodes

Cartwright, 2004) (Dofour; Guerena; Earles, 2003)	Cucurbits		
Medic, *Medicago litoralis* (Miles, C.; et al., 1996)	Carrot	Strip intercrop in between carrot plots	Carrot root fly
Napier grass (ICIPE, 2003)	Corn	Intercrop Border crop	Stemborer
Nasturtium (Ellis; Bradley, 1996)	Cabbage	Row intercrop	Aphids Flea beetle Cucumber beetle Squash vine borer
Okra (Hasse, 1986; 1987)	Cotton	Border crop	Flower cotton weevil
Onion and garlic	Carrot	Border crops or barrier crops in between plots	Carrot root fly Thrips
Radish (Ellis; Bradley, 1996)	Cabbage family	Row intercrop	Flea beetle Root maggot
Rye (OIKOS, 2003)	Soybean	Row intercrop	Corn seedling maggot
Sesbania (Naito, 2001)	Soybean	Row intercrop at a distance of 15 m apart	Stink bug
Sickle pod (OIKOS, 2003)	Soybean	Strip intercrop	Velvet bean caterpillar Green stink bug
Soybean	Corn	Row intercrop	*Heliotis sp.*
Sudan grass (ICIPE, 2003)	Corn	Intercrop Border crop	Stemborer
Sunflower (CIKS, 2000)	Cotton	Row intercrop in every 5 rows of cotton	*Heliotis sp.*
Tansy (DA, Philippines, 1997)	Potato	Intercrop	Colorado potato beetle
Tobacco (Hasse, 1986; 1987)	Cotton	Row intercrop, planted in every 20 rows of cotton	*Heliotis sp.*
Tomato (Makumbi, 1996)	Cabbage	Intercrop (Tomato is planted 2 weeks ahead at the plots' borders)	Diamondback moth
Vertiver grass (van de Berg, Undated)	Corn	Perimeter crop	Corn stalk borer

Table provided by www.oisat.org

ROTATION GUIDELINES
Adapted from Eliot Coleman's The New Organic Farmer

These are general patterns that have been found by scientific researchers and farmers.

- Legumes, onions, lettuces, and squashes are generally beneficial preceding crops.
- Potatoes yield best after corn.
- Corn and beans are not influenced in any detrimental way be preceding crops.
- Liming and manuring ameliorate, but do not totally overcome the negative effects of a preceding crop.
- Carrots, beets, and cabbages are generally detrimental to subsequent crops.
- Legumes increase the available nitrogen in a field.
- Fruiting (tomatoes, peppers, eggplant, squash, etc.) crops are heavy feeders.
- Leaf crops are light feeders.
- Potato and winter squash are good cleaning crops.
- Onions do not compete well with weeds.
- Cabbages, clover and alfalfa are good at extracting nutrients from the soil
- Lettuces and cucumbers are not good at extracting nutrients.
- Squash, corn, peas and beans grow best when manure of compost is applied every year.
- Cabbages, tomatoes, root crops and potatoes grow better on ground that was manured the previous year.
- Crops in the same family will have the same diseases and pests and should not be grown in the same place two years in a row.
- Grain crops do well after legume crops.

YIELD AND VALUE WORKSHEET

The purpose of this worksheet is to practice predicting the yield and value of a crop.

Use the data from the **Crop Rotation Worksheet** to fill in the first two columns below.

Crop	Row feet	Expected yield	Price/lb wholesale	Price/lb Direct	Total price Wholesale	Total Price Direct
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						

Use the table from Johnny's Seed Catalog to calculate your expected yield. These are average numbers, but will give you something to work with until you have your own data. Do some research to find the wholesale and retail prices for your crops. Calculate the amount of money your crop would bring if sold wholesale or through direct marketing channels. Your research should include looking at the organic price index (OPX) on www.newfarm.org , grocery stores, farmers markets, if available, and information from the web. Total the expected revenue from each of the marketing options and write below the appropriate column.

UNIT 6 – COMPOSTING

I. INTRODUCTION

II. COMPOSTING ASSESSMENT

III. TYPES OF COMPOSTING

1. Hot Composting
2. Cold Composting
3. Vermicomposting

IV. USING COMPOST

1. Soil amendment
2. Soil mix
3. Compost tea

V. UNIT SUMMARY

INTRODUCTION

The breakdown of dead plant and animal materials is a natural process that is happening all around us. This natural process is the source for organic matter and plant nutrients in the soil. Composting is adapting this process to agriculture by managing large amounts of material at one time to produce more in less time.

Composting has been an integral part of farming throughout recorded history because it accomplishes two essential tasks: dealing with farm waste products and producing a soil amendment that enhances crop production. Over the years, many methods of composting have been developed due to the diversity of materials available and the broad range of farming systems.

Crops, too, dictate different types of composting methods. Most annual crops and grasses are dependent on bacterially-dominant soil biology, while woody perennials are dependent on a soil life dominated by fungi. Enhancing the soil biology for these different types of crops requires "hot" or bacterially-dominant composting for annuals and "cold" or fungal-dominant composting for woody perennials.

What we are managing in a composting operation are the organisms that feed on the composted material. One of the keys to successful composting is to understand these different organisms.

Compost is thought to be "fertilizer" by some. However, a chemical analysis of composts will show that they are relatively low in the elements, such as nitrogen, found in chemical fertilizers. Fertilizer standards were set to define the amount of nitrogen, phosphorous and potassium a substance contains. Using fertilizer standards, a typical compost might have an NPK analysis of 0.4, 0.4, 0.4.

The value of compost lies in its acting as an inoculant, adding organisms to expand the soil life biodiversity, and in providing the soil life with food. This soil life will build a stable structure that binds coarse soils together or loosens clay soils. This structure provides pore space for gas exchange and for water infiltration and retrieval. Compost also contains plant nutrients other than nitrogen, phosphorus and potassium.

COMPOSTING ASSESSMENT

Objectives:

1. *Identify two reasons why farmers make and use compost.*
2. *Relate the type of composting to the types of crops.*

3. Identify factors to consider when deciding whether to compost.

To compost or not to compost? This question was unheard of until recently. It was thought in the past that composting was a "must" for any organic farm. However, recent innovations in organic farming have eliminated composting in some systems. Before committing time and resources to a composting operation, an assessment of soil quality, resources and the farm plan should be considered.

Condition of the soil (soil quality) is the primary consideration in determining whether or not compost is necessary. A relatively low organic matter content of the soil indicates the need for the addition of compost. This is the fastest way of increasing soil organic matter content, provided ample compost is added.

In farming operations where a large quantity of waste plant material and/or manure is accumulated, composting is indicated. This is especially true of organic farms that accumulate animal manure. All manure must be composted completely before application to fields used for immediate food crop production. In the case of accumulated plant material, these can either be composted or incorporated into the soil.

The type of farming is another consideration. Fields and beds that are continuously cropped will need compost added to build and maintain the organic matter levels. However, fields where green manure crops are part of a rotation may not need additional material added. Also, pastures used for regular grazing may not need compost added, depending on the grazing management. The soil life present should be able to break down any manure on the surface in a properly managed operation.

SUMMARY

Farmers have composted throughout history because composting uses the farm waste products and produces a valuable soil amendment. Annual crops benefit from a "hot" bacteria-dominated compost while herbaceous crops are better served with a "cold" fungal-based compost. Before deciding to compost a farmer should consider the type and amount of farm waste, the condition of the farm's soil, and the intensity of crop production.

TYPES OF COMPOSTING

Objectives:

1. *Identify the active organism in hot and cold composting and vermicomposting.*
2. *Describe the differences between hot and cold composting.*
3. *List three high nitrogen materials and three high carbon materials used for composting.*
4. *Describe a vermicomposting structure that provides the ideal conditions for worms.*

There are two main methods of composting: hot and cold. These methods use specific materials and are done to provide food and increase biodiversity to soils for different kinds of crops. A third type of composting uses worms to break down the material.

Hot composting is the method most commonly associated with composting. This mixes carbon and nitrogen-bearing materials together to promote a rapid breakdown of the material. Cold composting is not as well known and understood as hot methods. It is used to promote the fungal decay of plant material for use with herbaceous crops. Vermicomposting uses earthworms to break down the materials.

No matter what type of composting is used, it is important to understand the biological processes involved and to manage the process properly. This will make it possible to produce a finished product of high quality with the least amount of management.

HOT COMPOSTING

Hot, or bacterial, composting refers to a technique where the temperature of the material is raised significantly during composting, to between 120 and 140 degrees F. The materials are mixed to attain a carbon to nitrogen ratio of around thirty to one. (Thirty parts carbon to one part nitrogen.) This is a ratio that provides a good balance of food for the decomposition of materials by bacteria.

With hot composting, we are managing the process to maximize the bacterial decomposition of the material used. The bacteria involved in this process need the same things that we do to thrive: oxygen, water, and food.

Availability of oxygen is important because bacteria that thrive in its presence turn material in the compost pile into plant nutrients and food for aerobic life in the soil. When oxygen is excluded from a compost pile, anaerobic bacteria reproduce and feed on the pile's contents. These anaerobic bacteria produce plant and animal toxins such as methane and formaldehyde.

Maintaining a sufficient amount of oxygen in a compost pile can be accomplished in a number of ways. The first is by incorporating some coarse materials in the construction of the pile. This will help prevent settling and compaction of the pile and keep channels open for an exchange of air between the pile and the atmosphere. Another is to regularly turn the pile. Turning releases the built-up carbon dioxide and introduces oxygen-rich air. Some experimentation has been done with layering perforated tubing to provide air exchange channels.

Managing water levels is also important in providing an optimal environment for aerobic composting. The bacteria in a compost pile need water to metabolize the contents of the pile and to reproduce. If there is not enough water available in the pile, the bacteria population will start to go dormant, slowing down the composting process. On the other hand, if too much water is present, the water will fill the air spaces in the pile. This will exclude the oxygen rich air and will also slow down the process. In the case of too much water, anaerobic bacteria will begin dominating the pile.

During periods of heavy rain, compost piles may become soaked with water, slowing down the decomposition. This can be avoided by covering the piles with tarps. There are also compost covers available. These exclude most of the water falling on a pile but allow air to circulate. During drought periods, piles may dry out rapidly and require regular watering.

The third thing necessary for successful composting is the right kind of materials or food to promote rapid decomposition by aerobic bacteria. This is commonly referred to as the carbon to nitrogen ratio (C/N). The usually recommended ratio is 30/1, or 30 parts carbon to 1 part nitrogen. Grass clippings and other green vegetation, manure, and urine-soaked bedding are relatively high in nitrogen content. Brown, dry vegetation such as leaves and straw are high in carbon content and have low or no nitrogen. By mixing these two types of materials in the proper proportions, we can provide the food needed to promote rapid decomposition.

Hot composting begins with accumulating enough materials to build a pile of sufficient size to provide a good environment for the decomposers. The minimum size for a pile is between three and four feet on any side. Windrows are the most common types of piles built in agricultural applications. These are piles that are built to any width and height, usually determined by turning equipment, and can be the length of the composting area.

Since the carbon and nitrogen content of materials varies (and the materials themselves vary from farm to farm), it is usually difficult or impractical to attempt to compute these in all cases. A good starting

combination is to mix the high carbon with the high nitrogen materials in a 1/1 ratio by volume, or about half-and-half. The pile should then be monitored and the mixture adjusted until the right mixture is found.

Materials for composting are available on most farms, whether or not animals are part of the operation. It has been thought in the past that animal manure was necessary for producing quality compost, but quality compost can be created by using available plant materials only, like fresh grass, leaves, hay or straw and crop residues.

One of the traditional ways of composting has dictated that the different materials should by layered separately in the pile. This results in compaction and matting of the materials, making turning the pile more difficult. The matting also creates areas where oxygen is excluded and anaerobic bacteria flourish. Mixing the materials when initially building the pile will result in faster decomposition and easier management.

As the pile is built, the materials should be moistened to provide water for the decomposers. The nitrogen-rich materials may be moist enough, but it is usually necessary to add water to the dry, carbon-rich materials. Both of these should be as moist as a wrung-out sponge or rag.

Providing air circulation in the pile is the other important part of building a pile. Using coarse materials like whole leaves and straw will accomplish this. Shredding the materials to a small size will promote faster decomposition, but will mean faster compaction and require more frequent turning to provide air.

A properly built compost pile, meaning a good combination of materials, adequate moisture and air circulation, will "heat up" within 24 hours. This means that the metabolism of the bacteria in the pile will increase, increasing the temperature within the pile. A good range of temperature is between 120 and 140 degrees F. If the pile fails to reach this range, it means that there is not enough nitrogen material, there is too much or too little water, or the pile isn't circulating air. Opening the pile and observing is the best way to determine what adjustments need to be made. If the pile's temperature reaches 150 degrees or higher, too much nitrogen material has been used. The temperature can be lowered by adding more carbon material. The other option is to let the pile cool down on its own and adjust the mixture in the next pile.

After a pile reaches its maximum temperature, it will maintain that temperature over a period of time, from a few days to a few weeks. Then the temperature will begin dropping slowly over time. This is due to the pile running out of air, water and/or nitrogen. When the pile reaches 90 to 100 degrees F and stays there for a few days, it's time to turn the pile. During

turning the moisture content should be assessed and water added if necessary. The turning action will incorporate oxygen into the pile while breaking up compaction. If nitrogen-rich material is abundant, some more may be added and mixed in during the turning. The pile will then heat up again and go through the same cycle.

The compost is "finished," or ready for use, when it has turned a dark brown to black color and most of the material is broken down enough that it is not recognizable. This takes from two to four months, depending on how the pile was built and managed.

COLD COMPOSTING

Cold composting is a fungal process that requires a different mix of materials and different management. Since it is a fungal process, the C/N ratio is different: 60/1. Fungi require a diet high in complex carbon compounds, or woody material. This includes wood chips and dry stalks from crops. These are moistened, mixed and piled up just like a hot pile.

It will take longer for the fungal population to reach the point where the maximum temperature of the pile will be reached. This maximum temperature should be approximately 10 degrees F above the air temperature. Piling fresh wood chips from live trees will mean a faster and higher initial temperature. This is caused by bacteria flourishing until the easily metabolized sugars and carbohydrates are used up. Then the temperature will slowly drop.

Managing a cold compost pile is much simpler than a hot pile. Management consists of monitoring the temperature and adding water occasionally. When the temperature of the pile drops to the air temperature, it usually means that the pile is too dry. Adding water should cause the temperature to go up again slowly. The pile is finished when the material is dark brown to black and mostly broken down.

VERMICOMPOSTING

Vermicomposting uses worms to decompose material in worm beds. These are beds that are constructed to contain the material and worms. The worms produce high quality compost that includes worm castings. The castings contain plant nutrients and growth hormones.

Using worms to compost requires an investment of time and money. It also takes education and skill development. Initial cost includes beds and protective coverings. Composting worms love cool, damp and dark environments and will breed optimally when these conditions are maintained. They will tolerate temperatures from 40 F to 80 degrees F. This

means that in areas where temperatures go above 80 degrees, some type of shade must be provided. And in areas where winter temperatures are lower than 40 degrees, the beds should be enclosed in a heated shelter. For this reason, most commercial worm composting operations are indoors.

Bedding in a worm bin is the living medium for the worms but is also used as a food source. Material that is high in carbon is used and is to mimic the worms' natural habitat, the forest floor. The bedding needs to be moist (often related to the consistency of a wrung-out sponge) and loose to enable the earthworms to breath and to facilitate aerobic decomposition. A wide variety of bedding materials can be used, including newspaper, sawdust, hay, cardboard, or peat moss.

The worms can be fed a variety of available materials from manure to crop residues. Any coarse material added should be shredded to encourage rapid breakdown.

SUMMARY

Three types of composting are hot, cold, and vermicomposting. Hot composting is based on the decomposition of materials by bacteria. Fungi are the primary decomposers in cold systems, and worms eat the organic material in vermicomposting systems. Materials used for both hot and cold composting are the high carbon, brown materials and high nitrogen, green materials, but the proportions are different. In vermicomposting, worms actually eat the bedding and food material and the compost is their waste products or castings.

USING COMPOST

Objectives:

1. *Identify two benefits to using compost as a soil amendment.*
2. *Describe how to use compost in a soil mix.*
3. *Identify the key to good quality compost tea.*

Compost is primarily used as a soil amendment to increase or maintain the organic matter in the soil. It can also be used in a starting and potting mix for plants. Another use is to prepare "compost tea" for use in a sprayer.

SOIL AMENDMENT

Finished compost added to the soil maintains or increases the amount of organic matter, depending on the amount used per unit of land. It also acts as an inoculant, adding to the diversity of the soil life, and adds food for these microorganisms.

Contrary to most advice on the subject, compost should be added to the surface of the soil. The action of tilling in or mixing compost into the soil does more harm than good. The mixing action harms the soil in two ways. The first is through the destruction of any existing structure that has been built by the soil life. The second is the mixing action introduces an abundance of oxygen. This stimulates a population explosion among the bacteria. The bacteria feed on the foods present, resulting in a net decrease in soil organic matter. The mixing action also kills off the beneficial fungi. This is especially important to avoid when adding compost to soil used for herbaceous plants that are dependent on a fungal-dominated soil community.

The soil life will be able to utilize any food spread on the soil surface and incorporate the organic matter into the soil, working from the surface downward. This is the way it happens in nature-the plant and animal debris accumulates on the surface and is used as the soil structure and quality is improved from the top down.

SOIL MIX

Compost can be used as part of a soil mix or potting mix for plants. This enables organic farmers to make their own soil mixes for little or no expense, rather than ordering and paying shipping on large quantities of certified mixes. It can be added to soil or soilless mixes to create a superior starting mix. Compost has been shown to help prevent disease in seedlings, such as damping-off disease. The same mixes can be used to produce seedlings.

An excellent starting mix can be made by mixing soil from the farm itself with compost. Soil is selected from the most fertile area or bed and mixed with sifted compost. Compost can be sifted through half-inch mesh hardware cloth mounted on a wood frame. The amount of compost added is determined by the soil type used. A loam soil may require only 10 to 15 percent compost added to the soil. A sandy or clay soil may need as much as 50 percent compost.

COMPOST TEA

Compost tea is a liquid extract of compost. It is made by "brewing" compost in a container with water. The tea is used to inoculate microbial

life into the soil or onto the foliage of plants, and to add soluble nutrients to the foliage or to the soil to feed the organisms and the plants present.

The key to producing high quality compost tea is in keeping the oxygen content of the brew high to promote the growth of aerobic microorganisms. This can be done using a purchased mechanism or by constructing one from common materials.

Compost tea should be used within 24 hours after brewing. It can be applied directly to the plants. This inoculates the plant surfaces with beneficial microbes and provides some foliar nutrients. It also increases foliar uptake as beneficial microorganisms increase the time stoma stay open, while at the same time reducing evaporative loss from the leaf surface. Compost tea can also be added directly to the soil as an inoculant to increase soil biodiversity and to increase the rate of breakdown of a green manure crop.

SUMMARY

The primary use of compost is as a soil amendment to add organic matter to the soil, and inoculate the soil with a diversity of soil organisms. Compost can also be used with either soil or a soilless mix to prepare an inexpensive, organic soil mix. Brewing the compost with water and adequate oxygen results in a tea which can be used as a foliar spray or applied directly to the soil.

UNIT SUMMARY

Compost is a result of the decomposition of organic material in a managed environment. The organic materials used are high-carbon, brown materials and high-nitrogen, green materials. Water and air are necessary for the action of the organisms, whether bacteria, fungi, or worms. The resulting compost is primarily used as a soil amendment, but can also be used in soil mixes and in compost tea.

LESSON PLANS WITH OBJECTIVES - COMPOSTING

I. and II. COMPOSTING ASSESSMENT

OBJECTIVES:

5. Identify two reasons why farmers make and use compost.
6. Relate the type of composting to the types of crops.
7. Identify factors to consider when deciding whether to compost.

LESSON PLANS:

1. Show students **a handful of compost** and remind them of the discussion in the soil chapter on humus. Make the point that composting is just a speeded up version of what happens naturally.
2. Use Unit 6 power point presentation slides 1-18 to present the information on composting.

III. TYPES OF COMPOSTING

OBJECTIVES:

1. Identify the active organisms in hot and cold composting and vermicomposting.
2. Describe the differences between hot and cold composting.
3. List three high nitrogen materials and three high carbon materials used for composting.
4. Describe a vermicomposting structure that provides the ideal conditions for worms.

LESSON PLANS

1. Download and show the short video on making a compost pile found at http://www.taunton.com/finegardening/pages/gvt004.asp

2. Make a **hot compost pile.** Plan to use the compost with the next year's demonstration plot.
3. Make a **cold compost pile.** Plan to use the compost on landscaping shrubs next year.
4. Set up a **vermicomposting** project for the classroom. Use the castings in the demonstration plot.
5. If it is not possible to compost outside, check out **the composting alternatives** page.

IV. USING COMPOST

OBJECTIVES:

1. Identify two benefits to using compost as a soil amendment.
2. Describe how to use compost in a soil mix.
3. Identify the key to good quality compost tea.

LESSON PLANS:

1. Discuss the way the compost that the students make will be used as a soil amendment.
2. Make up a soil mix using compost.
3. **Brew compost tea**. Use the tea on the plants in the demonstration plot.

VERMICOMPOSTING

Purpose: to establish a worm bin that will produce worm castings for use in the demonstration plot.

This activity can be done either inside or out, but temperatures of 55-77 degrees F are best for the worms. A portable bin allows for movement inside when it gets cold.

Gathering materials:

1. A 12 gallon plastic storage bin, styrofoam cooler or a wooden box can be used for the worm bin. Ventilation holes need to be punched or drilled in the bottom and sides of the bin, approximately every four inches. Use blocks to raise the bin off the ground. A tray underneath will catch any worm "juice" that seeps out.
2. Worms can be ordered from supply houses, purchased from bait stores or from another worm farmer. Two species of red worms, *eisenia foetida* and *lumbriscus rubellus*, work best for vermicomposting. They're also called bandling, red wigglers, or manure worms. You will need about a pound of worms for a standard bin. Do not buy nightcrawlers because they will not be happy in the bin.
3. The bedding can be shredded newspaper, shredded corrugated cardboard or shredded leaves. The bedding should be thoroughly wetted by letting it soak in water then thoroughly draining and wringing it out. It should feel like a wrung out sponge when you put it in the bin.
4. Vegetable scraps can be accumulated to feed the worms, but do not feed them for the first few days, as they get acclimated. They will be eating the bedding. Do not feed the worms meat or greasy food.

Building the bin:

1. Fluff up the bedding material and place a thick layer in the bottom of the bin. Place the worms on top of the bedding material and watch them disappear into the bedding.
2. Cover the bin and wait a few days to feed them. The scraps should be buried under at least an inch of bedding material. The location may be determined randomly or divide the bin into quadrants and feed in a different quadrant each time. With the quadrant method you can check to see that all the food is being eaten. Excess food will start to rot and smell, so don't feed too much.

Harvesting the castings

1. As the castings start to build up they can be harvested in several ways. Worms like it dark and where there is food. If you open the bin, the worms will go deeper and you can remove the top layer, where most of the castings can be found. Alternately, you can consistently bury the food on one side of the bin, and harvest the other side where there will be few worms.
2. If you want to harvest the whole bin at once, it can be emptied into a small swimming pool and the worms removed and placed in a newly prepared bin.

Using the castings

1. The castings make wonderful soil amendment which can be used on the demonstration plot.

Data sheets:

1. A data sheet can be kept on the amount of food the worms eat.
2. A data sheet can be kept on the reproduction and production of castings by the worms.

Resources for more information about vermicomposting:
http://www.bae.ncsu.edu/topic/vermicomposting/pubs/worms.html

http://www.ciwmb.ca.gov/Publications/Schools/56001007.pdf

Feeding Data Sheet

Date	Weight of food	Total weight of food	Temperature	Burying location #	Type of food

Food burying locations- write these on the lid of the bin, so you can keep track of where to bury food next. Each day worms are fed, put the food in the next space. Check to see if there is left over food in the previous feeding location.

1	2	3
4	5	6

Calculate the average weight eaten per day. _____

Calculate the average temperature in the bin. _____

Data Sheet on Reproduction of worms and production of castings

Date bin set up _____

Date bin taken down _____

Total days worms in the bin _____

Initial weight of the worms _____

Final weight of the worms _____

Difference between the final and initial weights _____

Approximate initial number of worms _____

Approximate final number of worms _____

Difference between final and initial numbers _____

Initial weight of castings _____

Final weight of castings _____

Questions:

1. About how much food do the worms eat in a week?
2. What kind of food do they seem to prefer?
3. Did the number of worms increase?
4. What kind of worm behavior did you observe?
5. What happened to the bedding material?
6. Draw an illustration of the vermicomposting cycle from establishing the bin through harvesting the castings, to putting on a vegetable plot, to vegetable scraps, etc.

COMPOST PILE – HOT

Purpose – Build a hot compost pile that is at least 3'x3'x3' to produce compost for the demonstration plot.

This activity should be done outdoors, though modified versions may be done in the classroom.

1. Find a location for the pile that is convenient to water.
2. Gather at least ½ cubic yard of high-carbon, brown material such as fallen leaves, sawdust or straw. Gather an equal amount of high-nitrogen, green material such as grass clippings, vegetable scraps, or green weeds.
3. Loosen the soil under the proposed site of the pile and then cover with corn stalks, small twigs or other rough materials that will allow air flow under the pile.
4. Place small amounts of green and brown material in the pile and mix together, instead of layering. This will prevent compaction. Add water every 6-8 inches so the pile is damp but not soggy.
5. Small amounts of soil or finished compost can be added to ensure the composting organisms are present.
6. To ensure adequate heating of the pile, make sure that it is at least 3 feet high.
7. The pile may be covered with a tarp to prevent rainwater from leaching out the nutrients.
8. Measure the temperature in the center of the pile twice a week. The pile should heat up to 120-140 degrees F and stay there from a few days to a few weeks.
9. When the pile reaches 90 degrees F it is ready to turn.
10. Turn the pile using a fork. This will incorporate more air and the pile will heat up again.
11. The pile is ready when it has turned a dark brown to black color and most of the material is broken down and unrecognizable. This usually takes two to four months.

Data sheet

Identify the materials used in the pile.

Brown materials _____

Green materials _____

Size of the pile _____

Temperature of the pile

Date																		
Temp.																		

Questions:

1. What are the organisms most responsible for decomposing the materials in the compost pile?

2. List the basic requirements of these organisms.

3. How is composting like what naturally happens on a forest floor?

4. What is the benefit of composting to an organic farmer?

5. What is the disadvantage of composting to an organic farmer?

COMPOST PILE – COLD

Purpose – to build a cold compost pile to produce compost for the demonstration plot.

This activity should be done outdoors.

1. Locate an out of the way location that will be easy to water.

2. Loosen the soil under the proposed site and pile high carbon materials such as wood chips and dry stalks from crops up into a 3'x3'x3' bed.

3. Moisten the bed as it is made.

4. Take the temperature of the bed once a week. The temperature should slowly rise until it is about 10 degrees F above air temperature. When the temperature falls, moisten the bed again.

5. The compost is done when the color is dark brown to black and the materials are mostly broken down. This will take longer than the hot compost bed.

Data sheet

Identify the types of materials used _____

Size of the pile _____

Temperature

Date																		
Temp.																		

Questions:

6. What are the organisms most responsible for decomposing the materials in the compost pile?

7. List the basic requirements of these organisms.

8. How is this type of composting different from hot composting?

9. Which parts of the pile seemed to be the slowest to decompose?

5. Explain why these areas were slower to decompose?

BREWING COMPOST TEA

Purpose – to prepare compost tea to use on plants in the demonstration garden.

This activity can be carried out either outside or inside. It is based on the description by Dr. Elaine Ingham in *Kitchen Gardener* Magazine found on the web at *http://www.taunton.com/finegardening/pages/g00030.asp*

Materials needed are a 5 gallon bucket, a little molasses, good well-aged compost, an aquarium pump, plastic tubing, a gang valve and three bubblers.

1. Fill the bucket half full of compost, but do not pack. Compost should be loose.
2. Connect the pump and the gang valve with a piece of tubing. Attach three lengths of tubing to the ports on the gang valve. Each tube should be long enough to reach the bottom of the bucket when the gang valve is hung on the lip of the bucket. Attach a bubbler to the end of each tube.
3. Fill the bucket to the brim with water. Arrange the bubblers under the compost equidistance from each other, to aerate the whole bucket.
4. Add about 1 tablespoon of molasses and stir the mixture vigorously with a stick. Readjust the bubblers to be equidistance from each other.
5. The tea should brew for about 3 days. Stir the tea several times a day.
6. After three days, turn off and remove the aeration equipment and allow the mixture to sit for a half hour so the solids settle on the bottom.
7. Pour the mixture through a strainer (fine mesh screen, cotton material, etc.) into another bucket.
8. Use the compost tea immediately to spray on the leaves of the plants of the demonstration plot.

Questions:

1. What is the purpose of making compost tea and spraying it on plants?

2. Why do you need to aerate the tea as it brews? What organisms are of concern?

COMPOSTING ALTERNATIVES

Composting can also be done in the classroom in 2 liter plastic bottles. Both worms, hot composting and cold composting can be done in bottles. Visit this web site for specific directions on making decomposition columns.

http://www.bottlebiology.org/

UNIT 7 – MARKETING AND ORGANIC CERTIFICATION

I. INTRODUCTION

II. MARKETING BASICS

1. Importance of marketing
2. Market research
3. Marketing plan

III. DIRECT MARKETING TYPES

1. Farmers' Market
2. CSA
3. On-Farm market
4. Internet markets
5. Restaurant sales
6. Agri-tourism and entertainment farming
7. Farmers Cooperative markets
8. Wholesale markets

IV. CERTIFICATION

1. Benefits
2. Steps to certification

INTRODUCTION

Marketing can make or break a small farm. Products must be sold for a farmer to make a profit. Farmers don't start farming in order to market, and often do not have the skills and knowledge to be successful marketers. The skills and knowledge can be learned, though, and a successful marketing plan carried out that will ensure the viability of the organic farm. This often overlooked area needs to be emphasized with those who want to start an organic farm.

Organic farms tend to be different from conventional farms in that they are often smaller, grow a wider variety of crops and direct market. By direct marketing they can be "price makers" instead of "price takers". Direct marketing to the consumer who will use the product allows much more control, flexibility, and higher prices than selling to a wholesale distributor who determines the price. This is a good option for a farmer with a low to mid- sized volume of produce. The other side is that the time, energy and knowledge required to direct market is much greater. Some farmers estimate that they spend half of their time in marketing related tasks.

Organic certification allows a consumer to know that a farmer is following minimum standards set by the USDA in the National Organic Program. The farmer must apply for certification and follow a set of steps including an inspection to become certified.

AN INTRODUCTION TO MARKETING

Objectives:

1. *State why marketing is important to a small farmer.*
2. *List three types of records that should be kept.*
3. *Explain why a marketing plan is needed before planting a crop.*
4. *Describe the two general sources of information for market research.*
5. *Explain why market research should be done before starting a business.*
6. *List the 6 steps in a marketing plan.*

THE IMPORTANCE OF MARKETING

Before planting a seed, there needs to be a marketing plan. The plan will specify the quantity and variety of produce that is needed at a certain

time, so that, in turn, will determine the crops that need to be planted. Without a market, the crops go to waste, so having a plan for marketing increases the small farmer's chance at success. The marketing plan should be part of a comprehensive business plan. Resources for writing business plans can be found at http://www.attra.org/attra-pub/PDF/agriculture_planning.pdf

Marketing is not just advertising, though advertising is a part. Marketing involves determining what consumers want and getting it to them they way they want it, for a profit. The direct marketer has to be tuned in to the target audience and constantly watching and responsive to shifts in consumer preferences. Feedback from consumers is not hard to get when selling directly, but paying attention and responding is very important.

Keeping good records allows a farmer to know whether or not money is being made on a specific crop. Field records, harvest records, and sales records will give the farmer the data to calculate the amount earned per unit of land for each crop ($/acre, $/bed, $/1000 sq. ft.). Time should be taken at the end of the season to do an analysis of the records so that decisions for the next season will be based on actual data. Preparing the record sheets before the season starts will help to ensure consistent record keeping. Record keeping is a discipline that must be mastered. It allows the farmer to base farm decisions on reality instead of perception.

MARKET RESEARCH

Before starting a new business, market research needs to be done to determine the likelihood of success. The potential price and volume of product that can be sold will determine the projected income. Information about potential buyers and competitors will be essential in developing successful strategies. The first step is to decide what questions need to be answered to develop a successful marketing plan. The next step is to identify the information that is needed to answer those questions.

This type of information can be obtained in two general ways. Going to secondary sources involves finding information that is already published. Population, demographic, and regional information can be obtained from the chamber of commerce or census records. Libraries, extension agents, books, magazines, USDA publications, and web sites are stocked with relevant information.

Primary data is collected by communicating with people directly. Observing and talking to farmers and customers at farmers' markets will provide a good insight into that type of marketing and what the customer is looking for at the market. It is also worthwhile to talk to produce managers,

health food stores, restaurant chefs, family and friends about their preferences and buying patterns.

The information gathered will help identify the potential for the product and avoid wasting money marketing to all the wrong people.

MARKET PLAN

The market research is used to develop a plan for connecting products with customers in a desirable manner in order to make a profit. While writing a plan will not guarantee success, it does mean that the important factors for success have been considered. A marketing plan should define the consumers, what services or products will be offered and strategies for advertising, promoting or presenting the products to the consumers.

Step 1 is to assess the **present market situation**. Consider resources, products, markets available, personal strengths and weaknesses and current trends at the regional and national levels.

Step 2 is to set measurable **objectives**, both long term and short term. Reasonable, specific goals need to be set. Where would you like the business to be in 6 months? In a year? In 5 years?

Step 3 is to determine **marketing strategies** to meet these goals. The markets to be entered, types of advertising, promotion and types of presentations must be decided. Also, ways to differentiate your product from your competitors should be planned.

Step 4 is to make a **budget**. Estimate the costs of production and marketing and subtract from estimated income based on sales. Set up records to help you monitor the relationship between cost and income.

Step 5 is the **action plan**. Write down specific things that can be done immediately to implement the marketing plan.

Step 6 is to **evaluate.** This is a summary of your progress. Evaluation should be done on a regular basis, to monitor your success. Objectives and strategies may change with each evaluation, so a new cycle of planning will begin.

DIRECT MARKETING TYPES

Objectives:

1. *List three benefits of direct marketing*
2. *Identify the 5 common barriers to success in marketing*

3. Describe the benefits and challenges of 8 different types of markets.

Farmers capture a much higher share of the consumer food dollar when they market their produce directly to consumers. Direct marketing offers several benefits for farmers. Cash payment, premium pricing, and elimination of the middleman wholesaler draws farmers to these avenues of marketing.

Direct marketing makes sense for farmers who are producing low to mid-sized volumes of a variety of crops. USDA and other producer surveys indicate that organic farmers market directly much more frequently than do conventional farmers. Farms of less than 20 acres account for the majority of the direct marketing in Georgia. In 2002 only 3.3 percent of the sale of agriculture products was sold directly to individuals for human consumption in Georgia. Therefore, there is much opportunity for growth of direct marketing of fruits and vegetables in Georgia.

Each type of market has barriers to success that must be overcome to be successful in that market. Below is a list of the common barriers.

- Location of the farm in relation to population centers. This may determine the customer base.
- Special expertise, such as marketing or computer skills.
- Transportation is necessary for some markets. A reliable, appropriately-sized vehicle is essential.
- Physical resources are needed for each type of market. These will vary from a tent and table to more elaborate computer set-ups.
- Regulatory constraints refer to the licenses, fees, insurance, taxes, zoning regulations and certifications that are necessary for some markets

The following pages will give specific information on eight different markets that are available to farmers.

FARMERS' MARKETS

A farmers' market is a market in which producers from a local area gather to sell their own produce directly to the public. By selling direct the farmer is able to sell produce at retail. A farmers' market is a low-cost way for a beginning farmer to learn about retailing and to develop marketing skills. The cost to participate is usually low, and at a good market there are plenty of customers. Farmers' markets have been increasing in popularity in the last two decades and many areas have one or more markets.

Benefits

- Established customer base.
- Low marketing start-up cost.
- Small lots of produce acceptable.
- Immediate feedback allows testing of product line.
- Retail prices.
- Social contact, networking.
- Ability to promote farm and products.

Challenges

- Limited sales volume, since each contact is one to one.
- Time to prepare and be present at the market.
- People skills are a necessity.
- Retailing skills are also necessary.
- New farmers' markets take about three years to establish a loyal customer base.

COMMUNITY SUPPORTED AGRICULTURE

Community Supported Agriculture (CSA) is both a marketing strategy and a philosophy. The farmer sells shares in the next season's produce before the season begins. Each week of the season the shareholder will receive a "share" or box of fresh produce from the farm. In some CSAs the shareholders are involved in decision-making in all aspects of the operation, whereas in others, the farmer makes all the decisions. Each CSA is unique to the farmer and the community that is served. Involvement of the community may be extensive or minimal. Shareholders may pick up their boxes at the farm, at delivery sites, or home delivery may be offered. Recently, farmers have been developing e-mail communities that order their produce online and pick it up at a designated spot.

Benefits

- Farmer receives money before the season starts for seed, inputs, supplies, etc.
- Farmer markets in the off-season to recruit new members, and is able to concentrate on production during the season.

- Relationship with shareholders is at least a season long, and may extend for years.
- Community is able to share risk of farming with support and perhaps labor.

Challenges

- Crop production – as many as 40-50 different crops must be grown to provide diversity to shareholders throughout the season.
- Labor availability – crops are continually being planted and harvested, cleaned, sorted, and packed.
- Location –if the location of the farm is near enough to the customers, on-farm pick up is the least burdensome for the farmer; otherwise, delivery sites must be established.
- Shareholder retention – too much produce or too much unfamiliar produce will cause shareholders to drop out of a CSA.

ON-FARM MARKETS

On-Farm sales involves bringing people onto the farm to buy products. This strategy includes pick your own, agri-tourism and farm markets. The information presented here is directed toward farm markets located on the farm. This is probably the oldest method around of selling farm produce. Farmers have been selling produce to their neighbors since farms were started. Farm stands run the gamut from the back of a truck to an elaborate store. Many start out simple and become more substantial as the stand succeeds.

Benefits

- Farmer can work between customers.
- No direct competition with other farmers.
- Time is saved as there is no travel or packing to travel.
- Market can be set up at farmer's convenience.
- Customers generally come to buy.
- Customers build relationship with farm and farmer.
- Opens opportunities for other activities such as tours or workshops.

Challenges

- Attracting customers.
- Liability insurance is a necessity.
- Must have a building or stand to display produce.
- Farm must be kept neat and mowed.
- Farm must be close to population center.
- Potential customers may show up when stand is not open.
- Strangers coming onto farm property.

INTERNET MARKETS

Internet marketing can vary from a simple e-mail ordering system to a online store with shopping cart. All involve making a web presence with a list of products for sale and a way for customers to order the products. A system is put in place whereby the customer can pay for the products by credit card, third party vendor or check. Products may be delivered or picked up if the customers are local or shipped if customers are farther away.

Benefits

- Increased visibility of the farm.
- More information on the products can be offered.
- Ability to broadcast the message to thousands of people.
- Location of the farm is of little consequence as long as there is Internet access and shipping is convenient.
- Streamlined business transactions.

Challenges

- Intimidation by new and evolving technology.
- Good understanding of computers and on-line world is necessary.
- Technology and infrastructure costs.
- Increased personnel and administrative costs.
- Establishing customer trust.
- Product that can be shipped for a price people will pay.

RESTAURANT SALES

Locally-grown products are hot items in upscale restaurants today. Growing for this market can be both profitable and demanding. Offering a

high quality product and establishing a good relationship with the chefs seem to be the two key factors in successful restaurant sales. This can be one of a variety of marketing strategies a farmer can use to diversify his/her markets.

Benefits

- Price is often near farmers' market price and remains fairly stable.
- Increased visibility for farm, if farm sources are listed in the menu.
- Outlet for specialty products.
- Ability to work with the chefs to develop new products.

Challenges

- Restaurant business has frequent failures.
- Staff changes often.
- Demand for your product will change as season, chefs, and customer demand changes.
- Small amounts of product and frequent deliveries are sometimes required.
- Many restaurants purchase through institutional food service.

AGRI-TOURISM AND ENTERTAINMENT FARMING

Agri-tourism is "a commercial enterprise at a working farm, ranch or agricultural plant conducted for the enjoyment of visitors that generates supplemental income for the owner." This highly customer-focused type of agriculture may include outdoor recreation, educational experiences, entertainment, and accommodations. The farmer is able to supplement farm income by tapping into recreational dollars that customers are willing to spend on a farm experience. Small, diversified farms are ideal for supplying the type of farm experience customers expect.

Benefits

- Income from the public's recreational dollars.
- Public's desire for a farm experience is steady, though the type of experience desired will change.
- Ends farmers' isolation – opportunity to make new friends and links in the community.

Challenges

- Interference with main farm activities.
- Low profitability.
- Higher liability risk.
- Never off duty – holidays are work days.
- Degradation of the farm due to high volumes of cars and/or people.
- Complying with Americans with Disabilities Act.

FARMERS MARKETING COOPERATIVE

A marketing cooperative is a business owned and operated by a group of farmers selling similar products. The organization's purpose is to serve the farmers that use it by giving them more control over marketing their products so they receive a higher price; reduce the cost of marketing; and make the market more stable. In some cooperatives the farmers pool their purchases of inputs to reduce the cost. Cooperatives (co-ops) are operated on a not-for profit basis and are democratic in nature, with each farmer having one vote.

Benefits

- Market access due to consistent supply provided by multiple farmers and marketing activities by co-op manager.
- Transportation to final buyer is shared.
- Fair prices can be negotiated more easily as a group.
- Reduced risk due to shared ownership.
- Use of brands can promote the stability of markets.
- Marketing co-ops do not pay taxes on the profits they earn.

Challenges

- Enough produce must be grown in an area to justify a co-op.
- A legal business must be established with all the required paperwork.
- Farmers must put aside their rugged individualism, and work together to make the best decisions for the co-op.
- A percentage of the sale price will be retained by the co-op to perform the functions of the co-op.

- The skills of the co-op manager will determine the success of the co-op to a large degree.

WHOLESALE MARKETING

Wholesale marketing is defined as selling in quantity to a buyer who then resells the product. Most agricultural products in the US are sold through wholesale channels. Small farmers may sell wholesale directly to local grocery stores, natural food stores, food service establishments, and food buying co-ops or to buyers who then serve as the middle men in the marketing chain.

Benefits

- Ability to move large amounts of produce with one transaction.
- Contract for produce can sometimes be secured before crop harvested.
- Diversification in marketing strategies.

Challenges

- Price is determined by the buyer.
- Stricter regulations about sorting and packing.
- Large amounts of produce must be delivered.
- Consistent amounts and quality are desired by the buyers.
- Dependable delivery and invoicing must be established.

CERTIFICATION

Objectives:

1. *Identify the agency that certifies organic produce.*
2. *Explain 2 benefits of becoming a certified organic farm.*
3. *Name the 6 steps involved in getting certified organic.*

BENEFITS

All organic products marketed in the United States are regulated by the National Organic Program (NOP) developed by the US Department of Agriculture (USDA). To obtain organic certification, growers must conform to these standards and be certified by a private or state agency authorized by

the USDA. In Georgia, organic growers must also register with the Georgia Department of Agriculture. The rules for certification can be found at www.ams.usda.gov/nop.

The USDA organic seal allows the consumer to know that the products have been grown in accordance with the NOP standards. It is a safeguard to the consumer who does not know the farmer, that the products they are buying are the real thing. As organic products get moved around from one place to another, this seal has real value to the consumer. For the consumer who knows their farmer, there is little value in an outside agent determining what the consumer can know for himself, by a visit to the farm and conversation with the farmer. Type of marketing will determine if becoming certified organic is of value to the farm. Care must be taken, though if the farm does not become certified to avoid using the word "organic".

Some farmers find the discipline of record-keeping required to be certified a real benefit to the certification process. Field history, crop plan, sales records, rotations and fertility plans all have to be supplied to the certifying agent. These records help a farmer determine profitability of various crops as well as serve as planning tools.

STEPS TO CERTIFICATION

Selecting a certifying agent is the first step in the certification process. These agencies are approved by the USDA and a complete list with profiles of each certifier is available at www.rodaleinstitute.org/certifier_directory. Each agency has a unique price structure, application forms and methods. This web site makes it easier to find certifiers and compare them.

The next step is to fill out the application sent by the certifier. This will include records of inputs, production, harvest, and sales. Field history records will be needed. Livestock producers will have additional records to supply. The application is sent in and the certifying agency will send out an organic inspector.

The organic inspector will compare the information on the records supplied with the farm itself. Inspection of fields, crops, crop health, equipment and buildings will be made. Samples of soil, water or crops may be taken. The inspector will prepare a report which will be sent to the certifying agency.

The agency reviews the report and decides if the farm meets the standards for certification. If the farm meets the standards the certificate is issued allowing the farmer to label the farm products "organic" and to use the USDA organic seal.

Georgia organic farms must also register with the State Department of Agriculture and fill out the state registration form. A state inspector may visit the farm. This registration is free.

SUMMARY

Certification is regulated by the National Organic Program developed by the USDA. A farm that is certified is allowed to display the USDA organic certification seal on certified products, giving the consumer confidence that they are buying products that were produced in accordance with the national standards. The record-keeping discipline helps some farmers who would not otherwise keep the records necessary to determine profitability. The farmer must contact a certifying agency and fill out the application and supply all the records required. An organic inspector will visit the farm, inspect the farm and records and talk to the farmer about production and post-harvest handling practices. The inspector will submit a report to the certifying agency who will make the decision and issue the certificate if everything is in order.

UNIT SUMMARY

The importance of marketing cannot be overstated, as this is often not an area of strength or interest for farmers. Without successful marketing there will not be a successful farm. Marketing starts with marketing research which leads to the development of a marketing plan using the information obtained by research. Direct markets are often the best choice for a small organic farm and are varied enough that most farmers can find a market that fits their circumstances. Selling directly to consumers allows the farmer to keep all of the money spent on the products. Certification as "organic" is important to farmers selling to an organic co-op, to restaurants, to wholesalers or others who will be reselling the products. Farmers who are selling directly to those who will eat their products will have to determine the value to their customers of becoming certified.

LESSON PLANS WITH OBJECTIVES – MARKETING AND ORGANIC CERTIFICATION

I. AND II. BASICS OF MARKETING

OBJECTIVES:

7. State why marketing is important to a small farmer.
8. List and practice filling out three types of record sheets.
9. Explain why a marketing plan is needed before planting a crop.
10. Practice one of the two general strategies for obtaining marketing research information.
11. Explain why market research should be done before starting a business.
12. Make a marketing plan using the 6 steps for a fictitious (or not) farm.

LESSON PLANS:

1. Introduce the topic of marketing by telling the story of two farmers. Describe their successful farming practices but one should be growing something with limited appeal (artichokes, sunchokes, etc.) and the other should be growing something with wide appeal (tomatoes, corn, lettuce). Ask which one they think is more successful. You could emphasis one planning to market and the other not planning.
2. Use Unit 7 power point slides 1-5 to introduce marketing, market research and developing a marketing plan. As an alternative, use the power point presentation **Developing a marketing plan** which covers the objectives and more.
3. Discuss how a farmer knows if they are making money. Explain the information that must be obtained to determine profitability. Use the activity **Record Sheets** to allow the students to determine the information they need and go through the process.
4. Divide the class into groups of three and either assign or let them choose one of the **Market Research Poster Project** topics to research and report on. Some of the topics will be researched using direct strategies such as polls, surveys and observations and others will use indirect strategies such as gathering information from the internet,

magazines or books. Point out the different methods. Have the students present their research to the class by making and presenting a poster.

5. Go over the six steps in the marketing plan.

III. DIRECT MARKETING TYPES

OBJECTIVES:

4. List three benefits of direct marketing
5. Identify the 5 common barriers to success in marketing
6. Describe the benefits and challenges of 8 different types of market

LESSON PLANS:

1. Assign groups of students one of the farms in the **Marketing Plan Activity**. Copy the sheets describing the different marketing types for each group, and have them choose the best markets for their farm. Students should complete the first 5 steps of a marketing plan for their assigned farm. Have them describe how they will handle each of the common barriers to success in marketing. Have students decide if their farm will become certified organic and use the USDA organic seal.
2. Use Unit 7 power point slides 6-15 to present the different market options. The power point presentation **Horticultural marketing** could be used instead.

IV. ORGANIC CERTIFICATION

OBJECTIVES:

3. Identify the agency that certifies organic produce.
4. Explain 2 benefits of becoming a certified organic farm.
5. Name the 6 steps involved in getting certified organic.

LESSON PLANS:

1. Ask students if they have noticed the USDA seal and if they know what it means.
2. Use Unit 7 power point slides16-20 to describe the certification process.
3. If the Internet is available, bring up the Certifier Directory at http://www.rodaleinstitute.org/new_farm

Focus Questions – Taylorganic Farm

1. What different marketing strategy is Neil Taylor using on his farm?
2. How did he get into value-added marketing?
3. What are the advantages to value-added marketing?
4. What are the disadvantages to value-added marketing?

RECORD SHEETS

Purpose – to think through the types of information needed, a way to organize information, and how to analyze an example set of data to determine $earned/acre and quantity produced/acre for different crops.

1. Brainstorm for a list of the type of information that should be kept on a field history record sheet.
2. Do the same for a list of the type of information for harvest.
3. Do the same for a list of the type of information for sales.(Assume sales at a farmers' market.)
4. The class should look at the list and decide on the absolute essential information.
5. Using the field history record sheet as a model, the teacher can show the students a way they could set up the record sheet for 5 different crops. Enter fictional information that will be used by all the class.
6. Working in pairs, students should design two record sheets, one for harvest and one for sales of the same 5 crops.
7. Enter fictional information for each of the 5 crops in the record sheets.
8. Determine the quantity of crop /acre, bed or 1000 sq. ft. for each crop. Determine the $earned/ acre, bed or 1000 sq. ft. for each crop.

Questions:

1. Make a list of each crop and the amount of crop/unit of land.
2. Make another list of each crop and the $earned/unit of land.
3. Should these be the only considerations when deciding which crops to grow?
   If not, what other factors should be considered?
4. How can this information help a farmer make better decisions about the farm?
5. How would the record sheet for sales change if the market was a CSA?

MARKET RESEARCH POSTER PROJECT

These are group projects, performing market research for an organic farm. Groups can summarize their report on a poster and present to the class in 3-5 minutes. Some topics require direct research methods using primary sources and others use secondary sources. Some projects require telephone calls, visits to stores, etc. Allow time for students to work on these projects outside of class.

Topics
Direct research

1. Compare the price of specific organic fruits and/or vegetables versus non-organic fruits and/or vegetables. The produce should be the same. It would be best if at least 2 visits were made, a few days apart.

2. Survey of stores or markets in the local area offering organic produce. Be sure to survey the variety of produce and quality.

3. Compare the price of organic produce among various stores and markets. Be sure to compare the same items and visit more than once.

4. Survey the origin of organic produce and the certifying agent of the produce within a store.

5. Local survey of sources for organic produce. Places to check are natural food stores, grocery stores, farmers' markets, on-farm stands, roadside stands, restaurants, CSAs, etc.. Use of www.localharvest.org may be helpful.

6. Poll – Take a poll of teachers and staff. Suggested questions:

    1. Have you ever bought organic produce?
    2. Have you bought organic produce in the last month?
    3. Why do you buy organic produce? (if they have)
    4. What is the biggest disadvantage to buying organic produce?

Indirect

1. Where and how many organic farms are there in the United States and the world?

2. Is the nutritional quality of organic food better than food that is not grown organically? Be sure to use more than one source – this is a controversial topic.

3. Describe the history of the development of the National Organic Standards. Be sure to bring the history up to the current date, as there are new developments every year.

4. Explore the topic of pesticides and organic produce. Choose one of the following topics: the presence of pesticides on organic produce, the effect on the environment of growing without pesticides or acceptable pesticides to use on organic produce.

MARKETING PLAN PROJECT

Each group of 3-4 students will be assigned one of the Farms. The group will start with the basic information provided, and build a story of their farm. Using the worksheet, the group will develop the information needed for the marketing plan. Some research will have to be done. Once the worksheet is filled in, a finished report can be written, with the same sections as the worksheet.

Marketing Plan Worksheet

1. **Present market situation**.

   Resources

   Products

   Markets available

   Personal strengths and weaknesses

   Current trends at the regional and national levels

2. **Objectives**, both long term and short term. Reasonable, measurable goals need to be set.

   Where would you like the business to be in 6 months?

   In a year?

   In 5 years?

3. **Budget**.

   Estimate the costs of production and marketing and subtract from estimated income based on sales. Carefully consider the reasonable costs

of production of your crop and marketing costs, depending on the type of marketing you choose. Sales numbers should be consistent with the volume and type of marketing chosen.

Set up records to help you monitor the relationship between cost and income.

4. **Action plan**.

   Write down specific things that can be done immediately to implement the marketing plan.

Marketing Plan – Farms

1. Farm A is run by a young couple who are leasing 12 acres of bottom land from the husband's uncle. They live in a small house about a mile down the road. They are growing a variety of produce from beans to squash to peppers to tomatoes. The wife has a part time job in town, and the husband works fulltime on the farm. They have an old tractor and a few implements.

2. Farm B is owned by a middle-aged man who inherited the farm from his parents. His parents and grandparents grew cotton. The farm is 85 acres of mixed woods and fields. He works and lives full time on the farm. He grows some cotton, but mostly sweet corn and soybeans. He has a lot of old, but useable equipment. He uses sustainable practices and would like to transition to organic. He has a helper who has worked with him for many years.

3. Farm C is a student organic farm on a university, run by the students. There are 5 acres and a small tractor and implements. The farm also has a small greenhouse. Most of the production centers around salad ingredients, such as lettuce, greens, tomatoes, cucumbers, and carrots.

4. Farm D is a berry farm owned by an older, retired couple who have been growing berries for 20 years. They have 2 acres in strawberries, 2 acres in blackberries, and 5 acres in blueberries. About 5 years ago they switched to organic growing practices. They have a hard time finding anyone to help harvest the berries. They have a modest house on the farm.

5. Farm E is owned by a retired military man. He grows mostly fruit, such as figs, muscadines, blueberries, pears, apples, and strawberries. His home is on the farm of 8 acres. He uses a local commercial kitchen to turn the fruit that does not sell into value-added products such as jams and jellies. He has an intern that works with him.

6. Farm F specializes in herbs. The young woman who runs the farm grows many types of herbs on 3 acres. She does all the work herself with hand labor. She has no tractor and lives in a trailer on the farm.

7. Farm G is owned by a man who lives in town with his wife and 5 children. The farm is about 10 miles out of town. He works part-time as a lawyer and part-time as a farmer. His farm is 20 acres in corn and soybeans. He has been putting in an acre of tomatoes the last couple of years. He has a big tractor and lots of equipment.

8. Farm H is on 4 acres of land owned by a housing community. The farm is run by a single man who lives in the community. He grows a large diversity of vegetables and fruit to serve the needs of the people of the community. The community pays him by giving him a percentage of what the farm makes. He has small power equipment.

9. Farm I is owned by two women. They have 60 acres with woods, a pond, and 20 acres in organic fields. They specialize in heirloom tomatoes and peppers. They use immigrant labor in their fields. They have a tractor and equipment, but no barn or preparation area. They live in the farmhouse on the farm.

10. Farm J is 2 acres in a subdivision with large lots. The woman that runs the farm works full time on the farm, getting help from her teen age children occasionally, while the man works a job in town. She grows cut flowers organically. She has a tiller and a small lawn tractor. She also does some design work for weddings and special occasions.

UNIT 8 – PRACTICAL APPLICATIONS DEMONSTRATION GARDEN

I. INTRODUCTION

II. GARDEN SITE SELECTION AND DESIGN

III. SOIL PREPARATION

1. Soil Amendments
2. Double Digging
3. Sources for amendments

IV. PLANTING AND MAINTENANCE

1. Planting dates
2. Bed layout
3. Protective materials and structures
4. Irrigation
5. Mulch

V. CROP PRODUCTION GUIDES FOR RECOMMENDED CROPS

1. Strawberries
2. Sweet onions
3. Potatoes
4. Sugar snap peas
5. Other vegetables

VI. UNIT SUMMARY

INTRODUCTION

Growing vegetables and fruit is more engaging, interesting and fun than reading about growing them. A hands-on component is essential to fully appreciate, illustrate and incorporate the principles presented in this curriculum. This unit is presented as one way that a teacher can set up a demo plot on a very small scale that will allow students to practice and experience what they are learning in the classroom. The rewards of tasty fruits and vegetables are secondary to those of real-life experience in growing organic vegetables and fruits.

Depending on the situation, the demo plot may be done in containers, a greenhouse, or a field. The particular crops chosen here were chosen because they work in a school calendar year, but other crops can be used. What is important is that the students are involved in everything from site selection, double digging, planting, seeding, weeding, to harvest. The confidence they gain from growing organic vegetables and fruits in this class will allow them to continue their efforts at organic growing.

Objectives:

1. *Plan and prepare soil to grow vegetables and fruits organically.*
2. *Plant and transplant the fruits and vegetables.*
3. *Weed and care for plants.*
4. *Harvest and eat the produce.*

GARDEN SITE SELECTION AND DESIGN

The recommended demonstration garden is 3.5 x 30 ft. and should be located in an area that gets full sun. The garden will contain strawberries and cool season vegetables to fit into a typical school year of September to May. Avoid proximity to trees and shrubs. The likelihood of pedestrian traffic and vandalism may call for location in an out of the way place or fencing.

After the site is located, a soil test should be conducted. Samples should be taken from at least 6 different places in the garden. A core of soil at least 6 inches deep should be taken from each place and then all cores mixed together in a bucket. A sample from this mixture can be taken to the local extension office to be sent to the Soil Testing Lab at UGA in Athens. Results can be obtained in about 2-3 weeks.

SOIL PREPARATION

Amendments

Results from the soil tests will determine what amendments are needed. Organic fertilizers include vegetable meal, composted animal manure, and mature compost. Additional amendments such as green sand, rock phosphate and dolomitic lime may also be needed.

To determine the amount of amendments to be added, consult "How to convert an inorganic fertilizer recommendation to an organic one" in Unit 2. Add about one-half of the recommended amendments as you are digging and the other half to the top after the bed is prepared.

Preparation Of The Bed – Double Digging

Double Digging is a method of deep tillage done by hand labor. A spade and fork are used for deep tillage of beds up to 24 inches deep. A trench is dug with a spade the width of the bed, removing the top 12 inches and the soil is reserved. The subsoil is then loosened with a fork to another 12 inch depth. Next, a section of soil is moved forward into the trench and broken up. The resulting trench is loosened with the fork and this is repeated for the length of the bed. The reserved soil from the first trench is used to fill the last trench at the end of the bed.

Sources Of Amendments

Sources of organic fertilizers, soil amendments:

Bricko Farms – Augusta	706-722-0661
Green Thumb – Augusta	706-863-0212
Country Gardens – Newnan	770-251-2673
Misty Mills – Lavonia	800-356-6283
Hastings Garden Center – Atlanta	404-869-7447
Grand Pa's Worm Farm- Macon	478-477-4748
Holt Heritage Farm and Supply-Kingston	770-608-4093
Longwood Plantation- Newington	912-857-4571
Nature Safe Fertilizer – Bradenton, FL	941-350-7291
SeaAgri, Inc – Dunwoody	678-232-9064
The Urban Gardener, Inc.- Atlanta	404-529-9980
Whippoorwill Hollow Organic Farm Covington	678-625-3272

Youngs Mill Farm- Kingston (transplants)	404-625-4744
Farmer D's Organics- Atlanta	404-325-0128
Organic Growing Systems, Inc. – Alpharetta	770-652-0658

Pike's Nurseries – Atlanta
Local Feed and Seed stores
Check www.georgiaorganics.org/organic_directory for a more details and a more complete list of suppliers.

PLANTING AND MAINTENANCE

Planting Dates

Optimum Planting Dates for middle Georgia:

September 1-15 – sow all vegetable seeds and water daily the first week
October 15-30 – transplant strawberries at the midpoint of the crown and water every other day for the first two weeks
November 15-30 – transplant onions by cutting back the leaves by half and watering daily for the first week

Bed Layout

2/3's of bed (20 ft.)
- 2 rows of strawberries (40 plants of Camarosa) 12" by 12" spacing
- 1 row of hybrid yellow granex onions (50 transplants) spaced at 5"
- ½ row of carrots (seed)
- ½ row of beets (seed)

1/3 of bed (10 ft.)
September to mid February
- 1 row of mesclun or leaf lettuce (seed)
- 1 row of kale or rape (seed)
- 1 row of spinach or swiss chard (seed)

Mid February to May

1 row of 10 broccoli plants spaced at 12”
2 rows of white potatoes (20) spaced at 12”

OR

3 cages of sugar snap peas (25 or 30 seeds per cage)

Fall Design

20 feet 10 feet

Strawberries		4”	6” Mesclun/Lettuce
Strawberries		12”	15” Kale
Onions		12”	15” Spinach/Swiss Chard
Carrots	Beets	10”	6 “
		4”	

Drawing is not to scale

Protective Materials And Structures

Frost protection can be provided with medium weight floating row covers. Light weight products are easily doubled to make an equivalent

medium weight. Have enough total material on hand to apply two medium weight layers for temperatures below 25 degrees F.

Beets, carrots, lettuce and swiss chard on nights below 28 degrees F.

Onions, kale, spinach and rape on nights below 25 degrees F.

Pike's, Green Thumb, and other retail home garden centers are sources of row covers.

Bird netting may also be needed for the strawberries. It can be bought from Home Depot, Lowe's or other home/garden centers.

PVC hoops may be made to support the row covers or bird netting. Spacing the hoops every 5 feet will require:

7 – ½ inch thin-walled PVC pipe 5 feet long

14 – ¾ inch pieces of PVC pipe 17 inches long

The ¾ inch pieces are hammered into the ground and the ½ inch pieces slip into this sleeve. PVC electrical or plumbing pipe can be obtained from home centers such as Home Depot or Lowe's.

Irrigation

Irrigation can be by black porous hose, drip tape, or drilled polypipe (1/16" holes every 8"). The bed will need 60 feet of hose so it can be doubled back on itself .

Mulch

Clean grass clippings, shredded hay, etc. may be used to mulch the bed. Around the bed shredded leaves or pine straw make a good mulch.

CROP PRODUCTION GUIDES FOR RECOMMENDED CROPS

Strawberry Production

Mid October is prime time to set out strawberry plants in mid-Georgia area. They make vigorous plants and strong fruiting crowns during the coolest months of our climate. Then, beginning in April of next spring, you will begin picking fully ripe, fresh homegrown fruit which will continue to ripen into late June.

Make sure the site has full sunlight, is near a water source, is free of nematodes, and can be dug a few weeks in advance to remove or turn weeds

under. The double dig method gives a superior, long lasting bed. If needed, about 5-10 pounds of lime should be put down and raked in, also, at this time. Prior to planting, broadcast 15 pounds of an appropriate vegetable meal or animal based fertilizer, and rake it into the surface of the soil as you do a final leveling of the bed. If compost is available add a one inch layer prior to leveling. The finished bed should be 4-6 inches high and 36 inches wide over the top. Make the bed rounded with the center of the bed slightly higher than the edges.

To locate your holes for setting the plants, set a retractable tape measure at 20' and place it 9 inches in from one edge of the bed and mark the soil every 12 inches. Move the ruler over 12 inches and mark your second row of holes every 12 inches. If you desire to grow your own transplants for use one year from now, refer to 'Home Propagation of Organic Strawberry Plants' for an alternative planting plan. Dig small, 4" deep holes (in pre-wetted soil if dry) and set each plant at the mid point of the crown when firming it in. Avoid planting too deep or too shallow. Trim away dead leaves and stolens as well as excess green leaves. Keep only one to two center leaves, depending on the amount and condition of the roots.

Lay a slow seep drip hose down the center of the bed and immediately begin to soak the bed for the next hour. Water 3 times a week for the first 2 weeks followed by once a week or less from November through mid February depending on rainfall. At that time, in February, apply 2" of hay or straw mulch. As the weather warms up, resume watering 2 to 3 times per week mid February through May.

During the month of March be prepared to frost protect blooms and fruit by covering the bed with floating row cover or heavy clear plastic film, about mid-afternoon prior to each night of frost. Uncover by mid morning the next day. Also, be prepared to protect fruit from bird damage during harvest time by covering with a ½ inch mesh polynetting. During the harvest season, practice good sanitation by removing and disposing of all spoiled fruit as well as diseased and dead leaves. This is the best prevention against fruit rots.

A well tested and easy to use organic mulch consists of applying a single layer of newspaper, and laying on top 2 to 3" of shredded hay or straw. This may be laid around the plants the same day they are set or at any time prior to mid-February. This mulch serves to hold moisture, provides a barrier to weeds, and maintains a dry barrier between fruit and soil which lowers fruit rot. Rainfall will easily pass through this mulch. To maintain a 18", weed - free aisle around the bed lay down a four-ply thickness of

newspapers and four inches of hay or old pine straw. If applied at planting time, this should maintain a good weed barrier for the season.

Our varieties of choice continue to be Camarosa and Chandler. The combination of excellent yields, large berry size and good taste far surpasses that of any traditional varieties we've compared them with.

We encourage you to use as many organic methods as possible including double digging your bed, applying compost and organic fertilizers, and using organic pest control measures. On a per plant or per square foot basis, Camarosa yields as much as 2.5 pints, while Chandler produces 2 pints for a 9 month planting.

Sweet Onion Production

Depending on when good quality transplants are available, the month of November is a good time to plant. The optimum stem diameter for transplants is pencil size. Bunches of 50 are easy to handle and should be kept shaded (cool & moist) during transplanting. Cut back the tops about one half (½) prior to setting.

Based on a 100 square foot bed which has been loosened with a spading fork, apply 10-15 pounds of a vegetable meal or well composted animal fertilizer. Also apply any other needed amendments such as lime, green sand, etc. Use a steel rake to lightly incorporate these and at the same time smooth and level the bed surface. For best results this bed should have been hand loosened initially, using the method of double digging.

Set the transplants about 5" apart in the furrow that's been dug about 2" deep. Firm in the soil along each row keeping the surface level. Use hand watering to uniformly soak the bed.

The drip hose should be adequate for subsequent, weekly, or as needed waterings. Carefully hand cultivate and weed though mid-March. At this time side dress about 5 pounds of organic fertilizer and lightly cultivate. Also about this time, a 2-3" layer of soft hay mulch is beneficial. About mid-May, or earlier, as the first tops fall over, completely withhold any further irrigation, and allow 2-3 weeks for all tops to drop, the bulbs to mature, and the tops to dry as completely as possible. During these 2-3 weeks, harvest at least twice a week, those bulbs that have dry tops. Cut off the dry portion of the stem. Cure and store the bulbs in a cool, shaded, well ventilated location. When properly grown, handled and stored, the final onions should still be firm and of good quality at Christmas time.

Potato Production

Mid-February is a good planting window for Irish Potatoes in East Central Georgia. Time tested varieties include Red Pontiac and White Kennebec . At least 48 hours before planting, cut seed potatoes into 4-5 pieces, each having at least one strong eye. Five pounds of medium to large tubers make about 100 seed pieces. Dust these pieces with 2 tablespoons of sulfur dust in a brown paper bag prior to planting. Roll and turn the bag to tumble the pieces. Sulfur is optional on sandy or light soils.

Double digging breaks up the soil hard pan and is the preferred method of bed preparation. At final leveling, place evenly and incorporate 10 pounds of cricket fertilizer or cotton seed meal per bed. Also apply any needed soil amendments such as lime and green sand. With a tulip bulb planter make 2" deep holes, 10" apart down the center row. Use a 12" spacing between rows, as well as a triangular pattern when making holes for the two outside rows. Place one seed piece per hole with the eye or sprout up. Fill in the holes with soil and level the bed. Water with the drip system until a 30" band is wet. Maintain good moisture, and weed weekly.

At 6 weeks after planting, side dress organic fertilizer at 5 pounds per bed, and make a final cultivation to stir it in, and remove weeds. This is also a good time to mulch with 3" of chopped old hay or wheat straw.

Check the foliage frequently for Colorado potato beetles and dust early when first detected. Pyrethrin or sabadilla dusts work well applied to wet foliage. When tops begin to dry in May withhold water completely, allow 1-2 weeks for drying of tops and begin digging those hills that dry first. Dry the tubers in a shaded, ventilated area.

Sugar Snap Pea Production

Mr. Joe Mason of McIntyre, Georgia, has developed a plastic lined vegetable cage which serves him well in growing tomatoes, bell peppers and egg plants. We have also found **sugar snap peas**, yellow and zucchini squash, pole beans, and cucumbers greatly benefit from this system. Air flow cooling is provided in hot weather by raising up a 5" flap at the bottom.

The backbone of the system is a 29" diameter by 5' tall cylinder made from standard concrete re-enforcement wire. Each piece cut from the roll should have 14 complete squares with the end of the 15th square being cut. Form the cylinder and hold it by tying each cut end of wire back into the uncut squares. The cylinder can be set on top of the prepared soil and staked at 2 or 3 places or it can be pushed 5" into the soil to stabilize it against wind movement. Two, 4-5 foot bamboo, wood or metal stakes should be driven on

opposite sides of each cage to secure them and the plastic against strong winds.

Sugar snap peas should be sown at 25 seed per cage from mid-January to mid-February.

Other Vegetable Production

Lettuce, kale, mesclun, carrots, spinach, swiss chard, and beets can all be grown from seed. Lettuce seed needs light to germinate, so do not cover. Spinach seed does not germinate well in warm soil, so wait till soil cools. Carrot seed have to be kept consistently moist until they germinate, which can be several weeks. Water well and cover with plastic till they germinate. Following the directions on the seed packages as far as spacing and depth of planting should give good results.

UNIT SUMMARY

Hands-on experience is the best teacher and a demonstration organic bed can provide a little bit of that experience for students. Directions for preparing, planting, and growing a bed in the school year time frame are provided in this chapter. The bed can be an ongoing complement to the material taught in the course.

SOIL TESTS

Purpose – to collect valid samples of soil for testing

Equipment needed:
Clean plastic or stainless steel pail
Shovel/trowel

Procedure:

6. Determine plot to be tested.
7. Take samples of soil about 6-8 inches deep, being sure to get representative samples from all layers.
8. Take samples in a regular pattern from the entire plot and place all together in the pail. Avoid low areas or other areas with a concentration of minerals or organic matter.
9. Mix samples well and take out a one cup sample to be sent to the lab.
10. The samples can be taken to the extension office who will send them to the Soil, Plant and Water laboratory in Athens, GA. Results will be mailed back in about two weeks.

DOUBLE DIGGING

Purpose – to prepare the demonstration plot by personally participating in the double digging process.

1. Mark off the area of the demonstration plot with string (3.5' x 30').
2. If the bed is dry, water it well and let it set for a couple of days.
3. Remove all grass and weeds, including roots.
4. Dig across the 3.5 foot side, making a trough 12" by 12" .
5. Put each shovel full in a wheelbarrow.
6. Use a spading fork to loosen the soil in the bottom of the trench. Push the fork in as far as it will go and move it back and forth to loosen the soil.
7. Dig out a second trench, placing the soil in the previous trench. Try to keep the soil layers intact, not mixing.
8. Loosen the soil in the bottom of the second trench with the spading fork.
9. Continue digging trenches and filling the previous trench until the whole bed is dug.
10. Place the soil from the first trench in the last trench dug.